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The Journal of
Bone and Joint Surgery

THE TREATMENT OF MALUNITED COLLES'S FRACTURES *

BY J. S. SPEED, M.D., AND ROBERT A. KNIGHT, M.D., MEMPHIS, TENNESSEE

From the Willis C. Campbell Clinic, Memphis

Surgical intervention is not required in all malunited Colles's fractures, especially in the milder cases. In a typical malunion of mild degree, there is a slight shortening of the radius with a mild dorsal angulation of the distal radial articular surface, but there is no derangement or involvement of the distal radio-ulnar joint. Patients will usually develop a painless, strong, useful hand and wrist, if adequate physical therapy is given, and if persistent active use of the part is continued.

Patients with malunited fractures accompanied by marked osteoporosis, fibrosis of the fingers and hand, and associated trophic changes of appreciable degree, are not satisfactory candidates for corrective surgery, and should have intense and prolonged physical therapy before any surgery is done. Otherwise, the patient will be unable to make use of the functional improvement which may be afforded by the correction of the malunion. It is only after the stiffness and pain have largely disappeared and the trophic and circulatory conditions have improved that surgery can be safely employed.

It should be kept in mind that, after a period of two weeks or more has elapsed following the fresh fracture, the use of manipulation alone to improve position of the fracture is not wise. In such a case, especially if the patient is elderly and osteoporosis is present, there is danger that manipulation will further comminute the fragments and fail to break up the impaction.

OPERATIVE CORRECTION OF MALUNION

In a study of sixty cases of malunited Colles's fracture in which surgical procedures have been employed, it is evident that no one type of corrective procedure is applicable in all instances. The type of procedure employed varies with the type of deformity and the degree of displacement. The objectives to be obtained by surgical correction are: (1) restoration of the part to as near its normal anatomy as possible; (2) improvement in the function of the part by compensatory procedures, such as resection of the distal end of the ulna; and (3) improvement in the appearance of the wrist itself.

SURGICAL APPROACH

In the earlier cases included in this study, the radial (lateral) approach to the distal end of the radius was employed. However, the dorsal approach is more satisfactory, be-

* Prepared for presentation at the Meeting of The American Academy of Orthopaedic Surgeons, January 1945, which was canceled in compliance with the request of the Office of Defense Transportation.

cause the fracture site is more easily exposed, and a more complete and direct view of the fracture is thus obtained. The approach is made in a longitudinal direction in line with Lister's tubercle, and usually extends for a distance of two to three inches (5 to 8 centimeters). It should be of adequate length, because a short exposure, even though it may be more satisfactory cosmetically, entails more vigorous retraction during the operation, and thus a greater local postoperative reaction ensues. The incision is extended through the deep fascia, and is carried down laterally between the extensores carpi radialis longus and brevis and the extensor pollicis brevis, and medially between the extensores pollicis longus and digitorum communis. Care is taken to avoid injury to the tendons and to expose the bone subperiosteally.

If excision of the ulna is indicated, a medial longitudinal approach is employed with subperiosteal exposure of the distal one to one and one-fourth inches of the ulna. The distal end of the ulna, including the styloid process, is excised by using bone-biting forceps, small rongeurs, and small, sharp osteotomes.

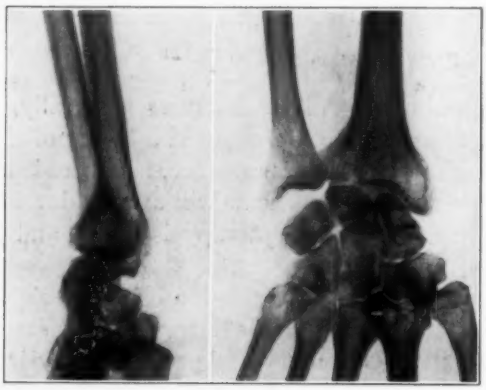

FIG. 1-A

FIG. 1-B

FIG. 1-A: Mrs. J. C. R., No. 41182. Malunited Colles's fracture, with good functional but poor cosmetic result.

FIG. 1-B: Radial deformity corrected by ulnar graft, wedged into radial osteotomy site. Prominent portion of ulna was removed for cosmetic reasons and used as graft.

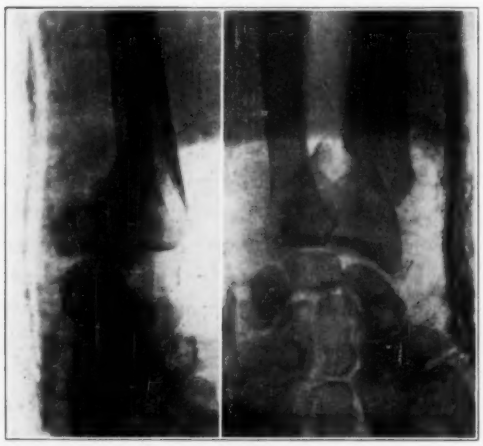

FIG. 2-A

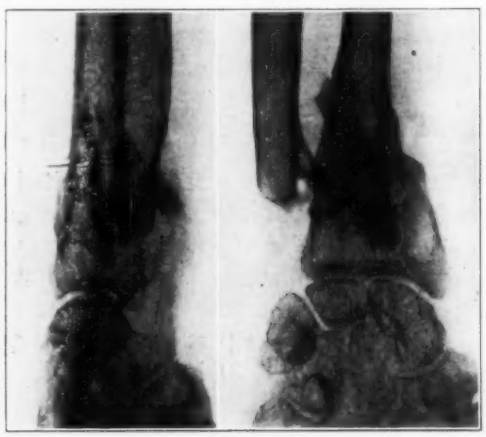

FIG. 2-B

FIG. 2-A: Mr. L. A. L., No. 57648. Unstable compound Colles's fracture with delayed union in malposition.

FIG. 2-B: Result one year after operation. Lower end of ulna was resected, permitting reduction of radial displacement; homogenous bone peg was used for stability of radial fracture. Excellent functional result; with exostosis, but not synostosis, of ulna.

SELECTION OF THE PROPER OPERATIVE PROCEDURE

Group 1

This group includes those cases in which the deformity consists chiefly of some dorsal tilting of the distal articular surface of the radius, associated with little or no radial shortening, and with no appreciable involvement of the distal radio-ulnar joint. Such fractures have usually been treated by a simple osteotomy of the radius without internal fixation. This procedure does not correct any abnormality in the relationship of the inferior radio-ulnar joint and, if such a disturbance is present, the procedure is inadequate. In this series, twenty-three such operations were done with satisfactory results in most instances, though there was partial recurrence of the deformity in approximately 20 per cent. of the cases. Recurrence took place during the period of immobilization, but in most of the cases in which it occurred, the recurrence was not of sufficient degree to impair the final result. In some instances, in addition to the radial osteotomy, the prominent medial portion of the ulnar head was removed for cosmetic reasons, without interfering in any way with the stability of the wrist.

Group 2

In those cases of malunion with broadening of the wrist due to radial shortening and associated prominence of the ulnar head, the procedure described by Campbell [1] has been used with good results (Figs. 1-A and 1-B). It consists of an osteotomy of the malunited radius at the old fracture site, a resected oblique portion of the prominent ulnar head being utilized as a graft to maintain reduction of the fracture. The removal of the prominent portion of the head of the ulna, in addition to furnishing bone for a graft, also serves to decrease the broadening of the wrist. Improvement from a cosmetic standpoint results, but radial length has not always been completely restored by this procedure.

Group 3

In many cases of malunion there is a more severe deformity than can be adequately corrected by either of the above procedures, and in such instances the use of a homogenous or autogenous intramedullary bone peg [2] for maintenance of the reduction of the osteotomized radial fragments has proved satisfactory (Figs. 2-A and 2-B). It should be stressed, however, that an intact, or at least satisfactory, distal radial surface is essential. When there is marked osteoporosis of the distal radial fragment, the use of the bone peg as internal fixation has been, in our hands, the only practical means of maintaining re-

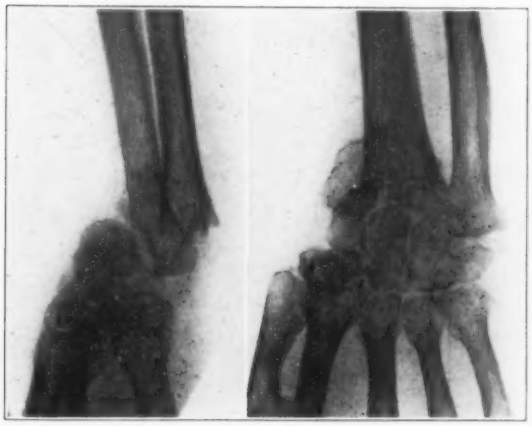

FIG. 3-A

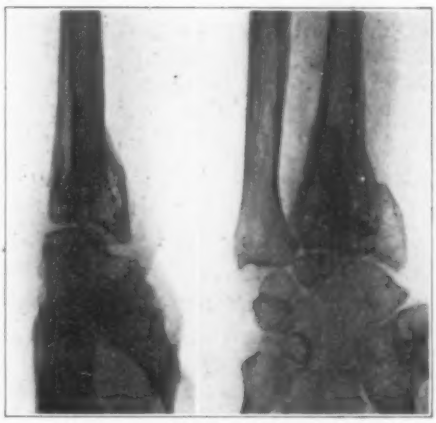

FIG. 3-B

FIG. 3-A: Mrs. J. M. H., No. 50351. Malunited Colles's fracture with marked deformity and moderate osteoporosis.

FIG. 3-B: Reduction was stabilized by use of homogenous bone peg. Excellent result nine months after operation, but excision of lower end of ulna may be necessary later.

duction of the fracture (Figs. 3-A and 3-B). This procedure has also been found useful in fresh and malunited reversed Colles's fractures, and fractures of the radial styloid with dorsal subluxation of the carpus. The bone peg acts as an internal strut to maintain the correction of the radial shortening and the dorsal angulation of the radial articular surface during the period of consolidation. If indicated, the lower end of the ulna can be excised, and the excised portion of the ulna can be used as a graft to fill in the defect at the site of the radial osteotomy, thereby making the radial fixation still more stable.

The details of the procedure are as follows: A small bone peg (about ⅛ by 3/16 by 1¾ to 2 inches in size) is inserted obliquely through the osteotomy site into the medullary cavity of the proximal radial fragment, and on through an oblique drill hole in the medial (ulnar) aspect of the radial shaft for a sufficient distance to permit reduction of the radial fracture. Then, after the fracture has been reduced satisfactorily under direct vision, the bone peg is tapped back into the shaft of the radius across the fracture site and well into

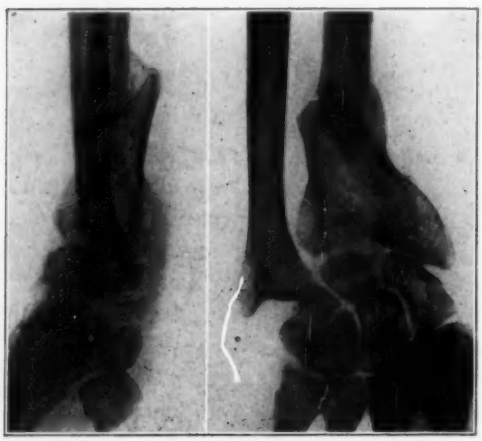

FIG. 4-A

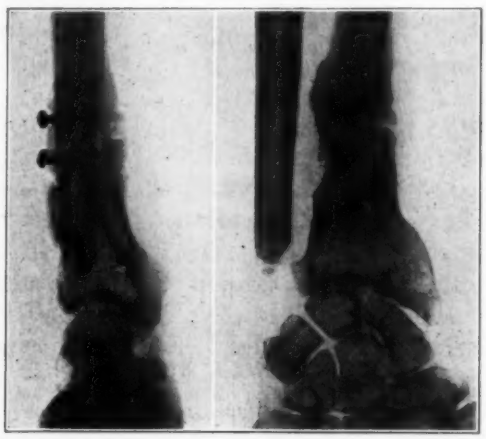

FIG. 4-B

FIG. 4-A: Mr. D. R., No. 57966. Malunion of oblique comminuted Colles's fracture, with radial shortening and ulnar prominence. Marked inferior radio-ulnar displacement.

FIG. 4-B: Result after step-cut osteotomy to gain radial length, and resection of lower end of ulna to correct discrepancy in length of radius and ulna. Resected portion of ulna was used as dorsal radial graft.

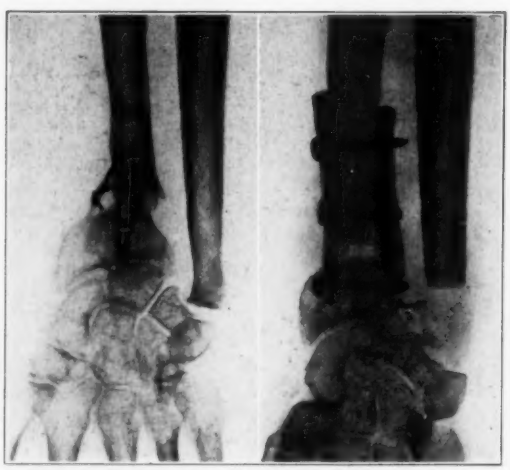

FIG. 5-A

FIG. 5-B

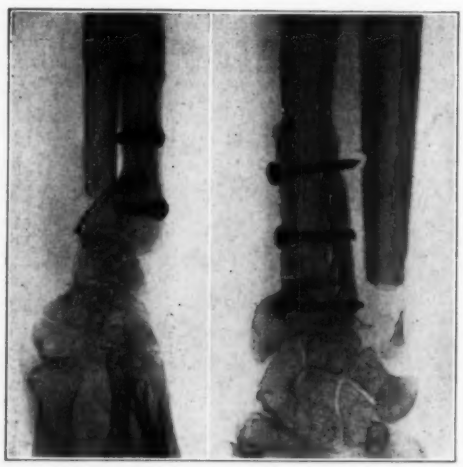

FIG. 5-C

FIG. 5-A: Mr. W. D. S., No. 50450. Non-union of Colles's fracture in malposition with marked radial shortening, following open reduction elsewhere.

FIG. 5-B: Dual bone graft employed because of osteoporosis of distal radial fragment. Lower end of ulna was resected.

FIG. 5-C: Good functional result nine months after operation.

the distal radial fragment, thereby stabilizing the reduction. Any excess portion of the proximal end of the peg is removed flush with the shaft of the radius.

Group 4. The Use of Onlay Grafts:

In one case in this series, internal fixation by means of an intramedullary bone peg did not prevent recurrence of the deformity following osteotomy. In this instance the problem was solved by utilizing a portion of the resected distal end of the ulna as a dorsal onlay graft, the graft being fixed by two vitallium screws. The result following this procedure has been quite satisfactory from both a functional and cosmetic standpoint. Similarly a second case of malunion, without previous operation, has been successfully treated (Figs. 4-A and 4-B).

In another instance a dual graft was applied (Figs. 5-A, 5-B, and 5-C). This type of fixation was indicated because of loss of bone substance with resulting non-union following an operation elsewhere. A solid union with an almost normal wrist resulted from the dual onlay graft. The pincers effect of the dual graft made possible the grasping of the distal osteoporotic fragment, and gave stability which could not otherwise have been obtained.

Group 5. Arthrodesis:

There are certain cases of severe malunion with marked deformity, where the radial fracture is situated close to the articular surface, and where there is marked osteoporosis or severe comminution of the distal radial fragment (Figs. 6-A and 6-B). In these cases it is apparent that a satisfactory movable wrist cannot be obtained, and wrist fusion is the logical solution to the problem. Usually resection of the distal end of the ulna is also necessary, because of the associated radio-ulnar disproportion and the inferior radio-ulnar traumatic arthritis which develops if the malunion is of long standing. The resected portion of the ulna can be utilized as a graft to aid in fusion of the radiocarpal articulation.

It should be kept in mind that it is not always possible to determine before operation whether an attempt at reconstruction should be made, or whether a wrist fusion should be done. This is well illustrated in the following case:

A man, thirty-three years old, was referred to the Clinic with severe bilateral Colles's fracture of six weeks' duration. At the time of operation it was felt that an attempt to obtain a movable wrist on the right was feasible, with a reasonable expectancy of a good functional result (Fig. 7-A). To date the

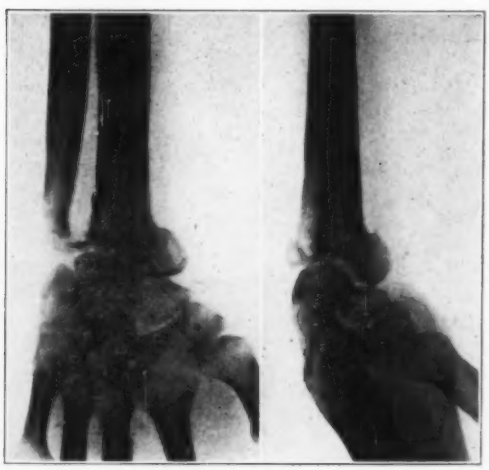

FIG. 6-A

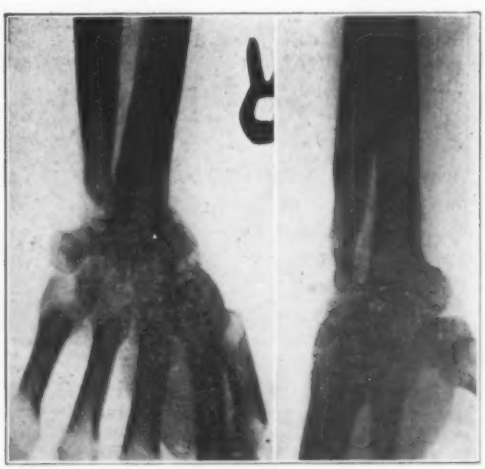

FIG. 6-B

FIG. 6-A: Mr. W. K., No. 40540. Malunited Colles's fracture after failure of reconstructive procedure.
FIG. 6-B: Result six months after fusion of wrist. Function was much improved, despite insufficient resection of ulna.

result is quite satisfactory, though at some future time it may be necessary to fuse the wrist, if sufficient traumatic arthritis develops. On the left (Fig. 7-B), the extensive comminution of the radial articular surface necessitated a fusion, and in this case a portion of the resected ulna was used as a dorsal graft.

Group 6. Resection of the Distal End of the Ulna:

In some cases which may be classified under the heading of malunion, the chief source of disability is an inferior radio-ulnar traumatic arthritis, following a long-standing derangement of this joint (Figs. 8-A and 8-B), or following an incompletely reduced radial fracture which enters into the joint. If the reduction of the radial fracture is satisfactory, and the traumatic arthritis is the major source of disability, resection of the distal end of the ulna will suffice. This is a simple procedure, the postoperative disability is

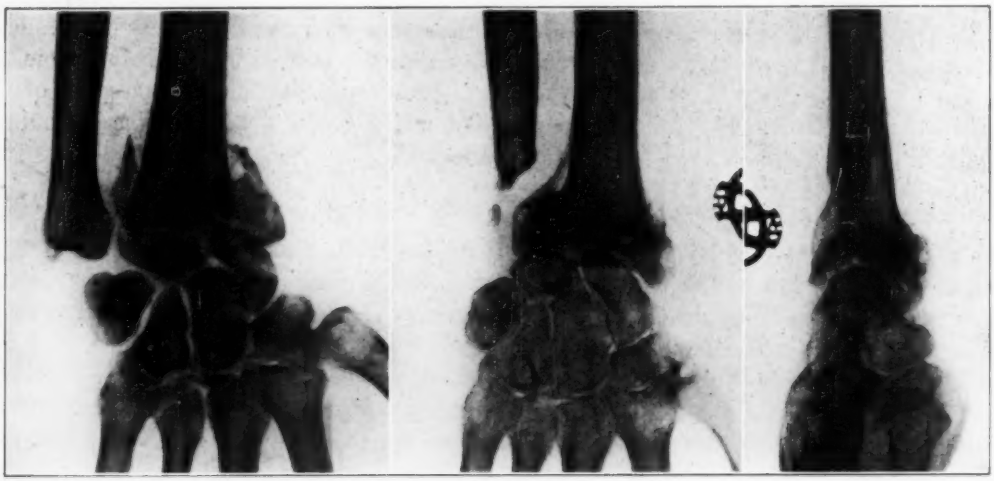

FIG. 7-A

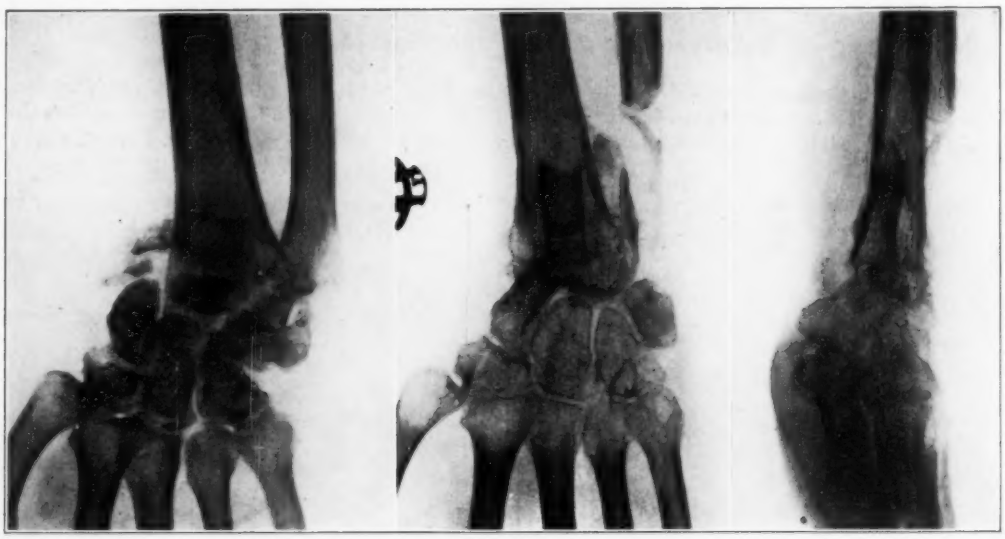

FIG. 7-B

This case illustrates the impossibility of determining preoperatively in every instance the exact type of reconstructive procedure which should be employed. The final decision frequently must be made at the time of operation. In this case, a reconstruction operation was accomplished in one wrist with a satisfactory functional result, while in the other, fusion was necessary.

FIG. 7-A: Mr. F. J. F., No. 61158. Right wrist: Reconstruction was possible with a reasonable expectation of obtaining a satisfactory functional result; however, subsequent traumatic arthritis may eventually necessitate fusion of the wrist. Result is satisfactory to date.

FIG. 7-B: Left wrist: Extensive comminution of the distal radial fragment necessitated primary wrist fusion, the resected portion of the ulna being used as a graft.

slight and of short duration, and the end result following the use of this procedure in properly selected cases is gratifying.

The possibility of reformation of the ulna after subperiosteal resection should be kept in mind, especially in the case of young adults and children. In these patients it is wise to excise the ulna extraperiosteally, since such bone reformation has occurred in some instances. In older adults and in the aged, this precaution has not been found necessary.

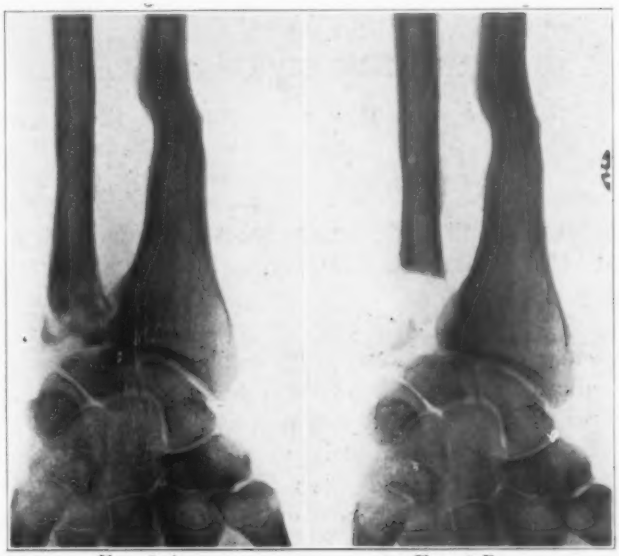

FIG. 8-A FIG. 8-B

FIG. 8-A: Mr. O. R., No. 59369. Old fracture of distal end of radius, with injury of inferior radio-ulnar articulation. There was severe disability, due to pain in radio-ulnar joint.

FIG. 8-B: Resection of distal end of ulna completely relieved pain and disability.

Postoperative Care

The postoperative care following surgical correction of a malunited Colles's fracture is quite similar to the postreduction care of a fresh fracture. One must not be satisfied with an unstable reduction for, not infrequently, recurrence of the deformity will take place in such cases. It is for this reason that the use of some form of internal fixation, whether a bone peg or an onlay graft, is advocated in all but the simplest of malunions.

Immobilization of the wrist should be maintained until union is complete, both clinically and roentgenographically, for otherwise recurrence of the deformity must be anticipated.

CONCLUSIONS

If malunion of a Colles's fracture is present to any material degree, surgical reconstruction offers an excellent chance of improving the appearance and function of the wrist. No single type of treatment is applicable in all cases, but the procedure must be chosen for each case, depending upon the exact lesion present.

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SURGICAL ANATOMY OF THE FLEXOR TENDONS OF THE WRIST

BY EMANUEL B. KAPLAN, M.D., F.A.C.S., NEW YORK, N. Y.

From the Department of Anatomy, College of Physicians and Surgeons, Columbia University, and the Hospital for Joint Diseases, New York

In surgery of the volar aspect of the wrist with its many tendons, the median nerve, and the two large arteries, precise knowledge of the relative position of these structures is important.

Even the experienced surgeon may find it difficult to recognize these structures. No wonder that occasionally, on reoperation in this area for previously performed sutures of tendons, the median nerve may be found united with a flexor tendon, the two having been erroneously sutured together.

A review of textbooks of anatomy and surgical literature shows that there is no detailed description of the relative position of the tendons of the wrist. As an example, Lewis, in Gray's Anatomy, in relation to these tendons, states only that the flexor digitorum sublimis, passing beneath the transverse carpal ligament, forms two pairs of tendons, the superficial pair going to the middle and ring fingers, the deep pair to the index and little fingers. There is no mention of the relation to the deep flexors or to the median nerve.

The present study was undertaken in an effort to discover whether or not there is a constant surgical relation of the superficial and deep flexors of the fingers to the median nerve and to the flexors of the wrist.

Observations were made on forty hands dissected by the writer, on sixty hands dissected by medical students during their regular instruction in the Department of Anatomy of the College of Physicians and Surgeons, and also on wrists operated upon by the writer during the past five years.

As a result of this, it became evident that there is a relatively constant relation between the tendons of the flexores sublimis and profundus to the index finger with the median nerve and with the tendon of the palmaris longus. This constant interrelation varies mostly in the presence of muscle or tendon anomalies.

The purpose of this article is to show the commonly encountered relation and to describe the variations of the tendons and the nerve that are important from a surgical viewpoint, as found in the literature (Testut, Le Double), and as seen occasionally by the author.

Anatomically the wrist is not a well-defined region. It may arbitrarily be confined between two transverse planes,—the proximal plane passing through the tip of the styloid process of the ulna, perpendicular to the long axis of the forearm, and the distal plane passing through the tubercle of the scaphoid and a point just distal to the pisiform bone.

In dissection from the volar surface to the deeper parts of the wrist, the superficial fascia first presents itself. Here are located the superficial veins, and the terminal branches of the medial antibrachial cutaneous nerve on the ulnar side, and the lateral antibrachial cutaneous nerve on the radial side. The palmar cutaneous branches of the radial, median, and ulnar nerves are seen emerging through the deep fascia.

The deep fascia is more dense in this region than the fascia of the forearm, especially in the distal part of the wrist.

The tendon of the palmaris longus can be seen and felt through the deep fascia in the mid-line of the wrist. The fascia forms a complete sheath for this tendon.

Slightly more radially and somewhat deeper may be seen the tendon of the flexor carpi radialis, which runs its course from the elbow to the wrist. The tendon of the flexor

carpi radialis is also completely enclosed in the deep fascia. The anterior layer of this fascia forms a much thicker cover than that formed by the anterior layer of the fascia for the palmaris longus.

The removal of the deep fascia for exposure of the subjacent structures is not easy, because it adheres to the most proximal part of the tendon sheaths of the flexores carpi ulnaris and radialis, which emerge from under the transverse carpal ligament, and also because the fascia is reinforced in this region by transverse fibers which form the superficial volar carpal ligament of the wrist.

The complete removal of the fascia and clearing of the tendon sheaths slightly change the normal relation of the tendons and the nerve. Cross-section studies, in addition to regular dissections, are therefore important.

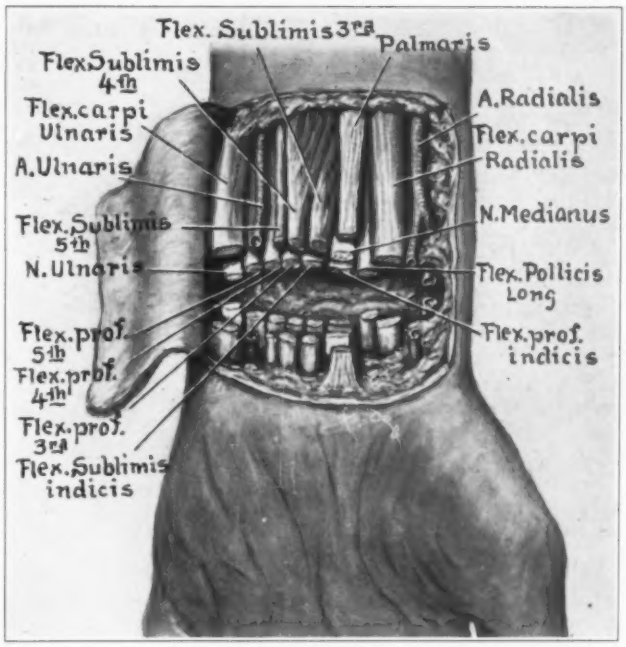

FIG. 1

A dissection of the anterior aspect of the wrist combined with a cross section of the flexor tendons and the median nerve.

To facilitate the description, an anterior dissection, combined with a cross section of the flexor aspect of the wrist, is presented (Fig. 1).

The tendon of the palmaris longus is normally in the mid-line of the wrist, continuing its course from the ulnar side of the humerus to the palmar aponeurosis.

To the ulnar side of the palmaris longus, on a slightly deeper plane, appears the flexor sublimis tendon to the middle finger; it is usually of considerable size. This tendon shows on its radial side fleshy fibers, arching in a proximal and lateral direction. On the ulnar side, this tendon is devoid of fleshy fibers for a much longer distance. Contiguous to it and on its ulnar side appears the flexor sublimis tendon to the fourth finger; medial to it, slightly deeper but intimately close, is found the flexor sublimis to the fifth finger. This last tendon is sometimes concealed under the ulnar artery which in its turn is covered by a double layer of the deep fascia, as shown in the complete schematic cross section (Fig. 2).

To the radial side of the palmaris longus is located the tendon of the flexor carpi radialis, and lateral to it appears the radial artery.

When the tendon of the palmaris longus is elevated and slightly retracted to the ulnar side of the wrist, and the fascia underneath is cleared, immediately under the tendon is found the median nerve. The nerve is located approximately in the same horizontal plane and to the radial side of the flexor sublimis tendon of the middle finger before it enters the carpal tunnel. At the proximal limit of the wrist, the median nerve is dorsal to the arching fleshy fibers of the same tendon. Here it almost constantly appears from underneath the arching fibers to continue its further course through the wrist to the palm.

When the median nerve is elevated and retracted to either side, the tendon of the deep flexor of the index finger is most commonly found under the median nerve.

To the radial side of the median nerve and the tendon of the flexor profundus indicis, in the space between these two structures and the tendon of the flexor carpi radialis, but dorsal to this last tendon, is found the tendon of the flexor pollicis longus.

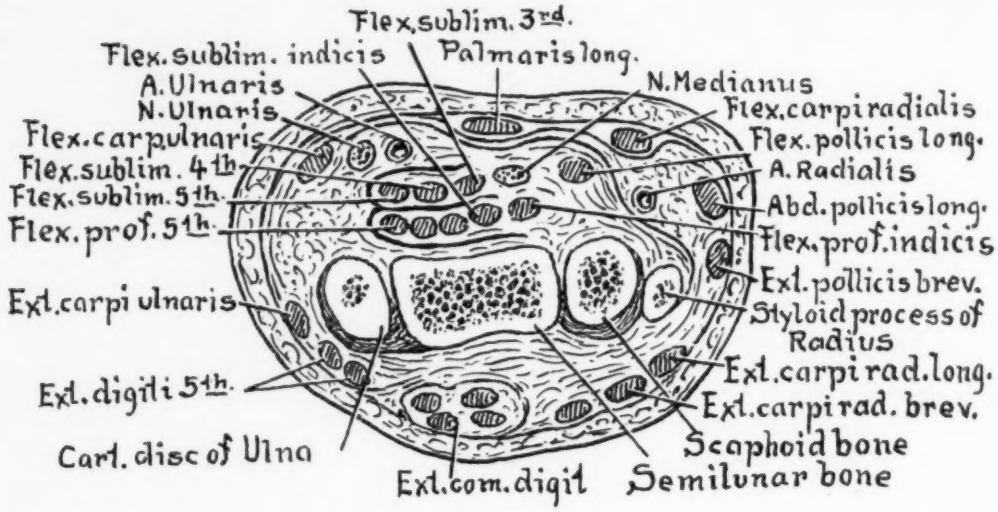

FIG. 2

A complete cross section of the right wrist. The distal segment of the section shows diagrammatically the relations of the tendon of the palmaris longus to the median nerve, to the flexor profundus indicis, and to the other flexor tendons of the fingers and wrist.

To the ulnar side of the deep flexor to the index finger, and slightly more anteriorly but underneath the tendon of the flexor sublimis to the middle finger, is found the tendon of the flexor sublimis to the index finger. To the ulnar side of the tendon of the flexor sublimis indicis are found the deep flexors to the middle, fourth, and fifth fingers. These last are approximately on the same level as the tendon of the flexor sublimis indicis, and are placed very close together, so close that sometimes they cannot be separated completely.

In a cross section of the wrist in which the plane of section passes through the styloid process of the radius and a point just proximal to the pisiform bone, the relationship of the tendons and nerve is shown. The diagrammatic illustration represents the distal part of the right wrist (Fig. 2).

This illustration shows that, in the average hand, the tendon of the palmaris longus can be considered as a key to the deeper structures. It leads in depth to the median nerve which is under the tendon of the palmaris longus, to the tendon of the flexor profundus indicis found under the median nerve, and to all the other tendons in their proper relation to the radial and ulnar side of the central column.

It may be noticed that the location of the deep flexor to the index finger does not change, whether the ulnar bursa (common flexor tendon sheath) includes the index flexors, or whether the index flexors have an independent sheath.

The tendons of the wrist present frequent variations which are a part of the variations of the muscles of the forearm. The complete description of these variations is beyond the limits of this article. To understand the variations it is important to know that they are not haphazard, but are an expression of differentiation of a common volar muscle mass, subject to definite developmental rules.

According to Lewis, in the human embryo, the development of the muscles of the anterior surface of the forearm begins as a common mass which gradually recedes from the wrist proximalward and splits into longitudinal units to form the adult muscles and tendons.

Considered from the viewpoint of comparative anatomy, the muscles of the volar aspect of the forearm form a common flexor-pronator group, originating from the medial epicondyle of the humerus, the ulna, and the radius, as an undifferentiated mass, which splits into distinct longitudinal units. The splitting and the development of the con-

stituent parts vary in accordance with the functional development of the hand of the corresponding group. Thus, in the reptilian hand, which moves as a unit without separate finger or wrist motion, the volar musculature of the forearm is said to be undifferentiated and undivided almost in its entirety. In man, the known complexity of the volar musculature is in full accordance with the functional demands of the human hand. In the intermediate groups, a wide range of combinations and divisions represent normal patterns for the corresponding group. Testut has shown that the human muscle variations often represent a modified form of a normal pattern, seen in a lower zoological group.

Most of the variations fall into definite groups and for simplicity are considered separately for each terminal group of tendons.

1. The Flexor Carpi Radialis

In this group there are:

a. Frequent insertion of the flexor carpi radialis into the greater multangular.
b. Insertion into the greater multangular and the scaphoid.
c. Insertion into the base of the metacarpals.
d. Insertion into the transverse carpal ligament.

While the first three insertions do not materially change the relation of the tendon, the fourth places the tendon more superficially and may lead to its confusion with the tendon of the palmaris longus, especially when the palmaris longus is absent.

2. The Palmaris Longus

a. The palmaris longus is absent in about 11 per cent. of cases according to Le Double. In the absence of this tendon, the author observed, in three instances, that the flexor sublimis indicis appeared between the median nerve and the tendon of the flexor sublimis to the middle finger.

b. The tendon may divide into two or three separate tendons.

c. Instead of a tendon, a muscle belly may be found.

d. The tendon may deviate from its mid-line position in the wrist to the ulnar side and become inserted into the pisiform bone, or into the abductor pollicis brevis.

3. The Median Nerve

Hovelacque found that a frequent variation of the median nerve is in its splitting into two longitudinal trunks. Occasionally, the nerve occupies a slightly ulnar position in relation to the palmaris longus, or shifts to a more lateral location in relation to the palmaris longus.

The flexors of the fingers and the thumb produce variations which are frequently interrelated.

4. The Flexores Digitorum Sublimis and Profundus

a. There is frequent extensive fusion of the tendons of the flexores sublimis and profundus to the fourth and fifth fingers.

b. Frequently there are accessory muscle and tendon slips to the flexor profundus and especially to the flexor profundus indicis.

In one of the dissected specimens, a supernumerary tendon of this type was found in both wrists. For experimental purposes, the normal flexores digitorum profundus and sublimis were completely severed in the wrist. The accessory slip originated in the distal part of the origin of the flexor pollicis longus and was inserted into the tendon of the flexor profundus indicis, near one of the lumbricales. Traction applied to the accessory slip produced flexion of the index finger.

c. The flexor sublimis to the fifth finger and to the index finger may be absent.

d. The flexor profundus to the index finger may be split into two independent tendons.

e. The flexor profundus indicis may have a common origin with the flexor pollicis longus.

5. The Flexor Pollicis Longus

a. The flexor pollicis longus may be absent, as normally observed in some of the great apes. The thumb is then found very much diminished in size.

b. The tendon may be divided into two or three separate slips with insertion into the scaphoid or into the transverse carpal ligament.

6. The Flexor Carpi Ulnaris

a. In the flexor carpi ulnaris, the tendon of insertion into the pisiform bone may become double.

b. It may fuse with the tendons of the flexor sublimis or flexor profundus.

c. The insertion may descend to the fourth or to the fifth metacarpal.

Figures indicating the incidence of the individual variations are not given, because they are not definitely available in the literature, and also because a specially conducted investigation on a large scale is required for definite conclusions. Nevertheless, the description of the most common variations is important as they are comparatively frequent, they form an integral part of the anatomy of the wrist, and they are necessary for proper surgical orientation in this region.

SUMMARY

The relative position of the flexor tendons and the median nerve is not adequately described in the literature. A study of the wrist showed a comparatively constant relation of the tendon of the palmaris longus to the median nerve and tendon of the flexor profundus indicis.

The anatomy of the tendons of the wrist and of the median nerve, as commonly observed, and also the surgically important variations of the tendons are presented.

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ROTATIONAL DEFORMITY IN THE TREATMENT OF FRACTURES OF BOTH BONES OF THE FOREARM

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The determination of the correct rotational position in which to immobilize fractures of both bones of the forearm is of importance, in that any degree of error will be followed by a corresponding limitation of rotational movement. Furthermore, accurate reduction of the jagged bone ends cannot be expected unless the rotational deformity is corrected; even a small inaccuracy may be sufficient to prevent the interlocking of the bone ends upon which stability in plaster depends.

The orthodox position in which to immobilize these fractures is that of full supination for the upper third, and the mid-position for fractures of the middle and lower thirds, these positions being based on the anatomical arrangement of the pronators and supinators of the forearm. However, it is unreasonable to suppose that all fractures at a given level will present the same degree of rotational deformity. Other factors may also be involved,—such as variations in the direction and leverage of muscle pull with varying degrees of angulation of the fragments, variations in the tension of the biceps tendon with flexion and extension of the elbow, and the effect of the interosseous membrane.

The position with respect to rotation in which such fractures should be immobilized is governed by the degree of rotation of the upper radial fragment, the upper fragment of the ulna being stable. Provided both the calibration of rotation and the immobilization are carried out with the elbow in the same degree of flexion, the position of the radius is constant for any given fracture. The following standard examination is suggested as a method whereby the rotational position of the upper radial fragment may be determined with some certainty. It is based on the roentgenographic appearance of the bicipital tuberosity in varying degrees of rotation. It is suggested that a calibration chart of the normal tuberosity be first made in the form of tracings on plain celluloid, in order that films may be superimposed for comparison. The chart may then be kept as a standard. As the estimation of rotation is made on the shape of the bicipital curve and the relationship of the cancellous portion of the tuberosity to the shaft of the radius (Fig. 2), individual variations in the general appearance of the bone are of no consequence. A comparable view of the normal elbow should always be taken to safeguard against error. For dealing with such fractures in children, a separate calibration chart should be made, as the curves of the bicipital tuberosity are more acute (Figs. 5-A, 5-B, 5-C, 5-D, 5-E, and 5-F).

In order to achieve standardization, a constant technique must be employed to demonstrate what may be termed "the tuberosity view". An anteroposterior view of the elbow joint is taken with the tube at an angle of 20 degrees (Fig. 3); the tip of the olecranon is placed one-third of the way along the plate, with the elbow joint flexed to 90 degrees, and care is taken that both condyles of the humerus are at the same level.

When a patient with fractures of both bones of the forearm is admitted, in addition to the usual views of the fracture, a tuberosity view is taken. The rotational position of the hand when this view is taken is of no importance, the only essential being the careful alignment of the elbow joint. The roentgenogram so obtained is then compared with the calibration chart, and an estimation is made of the rotational position of the upper radial fragment. A similar view of the normal elbow is then taken with the hand in the same degree of rotation, and the two tuberosity views are compared. A simple protractor (Fig. 4) is of value in determining the accurate position, both for taking the roentgenograms and for applying the plaster. After the degree of rotation has been established, the fracture is reduced by traction and manipulation, and immobilized in plaster in the deter-

FIG. 1-A

FIG. 1-B

FIG. 1-C

FIG. 1-D

FIG. 1-E

FIG. 1-F

FIG. 1-G

Calibration roentgenograms

Fig. 1-A: 180 degrees
Fig. 1-B: 150 degrees
Fig. 1-C: 120 degrees
Fig. 1-D: 90 degrees
Fig. 1-E: 60 degrees
Fig. 1-F: 30 degrees
Fig. 1-G: 0 degrees

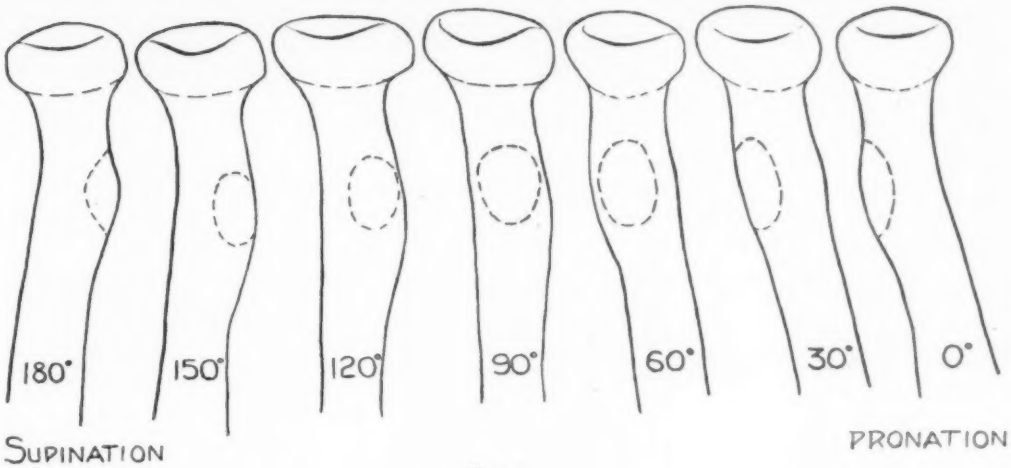

FIG. 2
Calibration chart

mined position. In the average case, the taking of the tuberosity view is not difficult. In compound fractures, the view may be taken through the plaster after the wound has been treated surgically, and in nervous patients a light plaster cast with the elbow in flexion of 90 degrees may be applied as a preliminary measure.

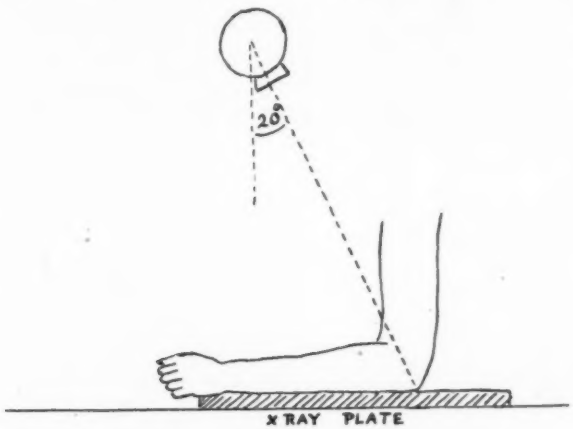

FIG. 3
Method of taking the "tuberosity view". The position of the condyles of the humerus is not clear in the diagram; they should be equidistant from the x-ray plate.

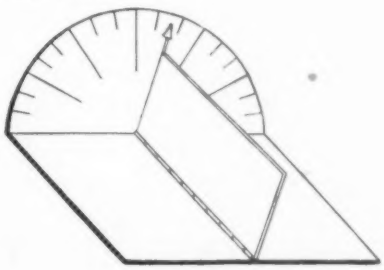

FIG. 4
Protractor for measuring rotation. The hand is laid against the vertical plate and the degree of rotation is read from the calibrated scale.

CASE REPORTS

For the purposes of this article full supination will be referred to as 180 degrees, the mid-position 90 degrees, and full pronation 0 degrees.

CASE 1. Boy A. was admitted with a recent fracture of the radius and ulna at the junction of the middle and upper thirds (Fig. 5-A). The fracture was reduced and immobilized with the wrist at 90 degrees. Post-reduction roentgenograms showed incomplete reduction with evidence of rotational deformity (Fig. 5-B). A tuberosity view was taken through the plaster (Fig. 5-C), which corresponded with the 135-degree view on the calibration chart. A tuberosity view of the normal elbow with the wrist in 135 degrees showed a slightly more prominent tuberosity (Fig. 5-D). The rotational position was taken at 130 degrees and a second reduction was performed with the wrist at 130 degrees. Figures 5-E and 5-F show the position after this reduction. Clinical union in satisfactory position was evident six weeks after reduction, and, when the patient was last seen, eight weeks after reduction, the rotational range was 30 to 180 degrees.

CASE 2. Sergeant E. was admitted with a recent fracture of the radius and ulna in the middle third. Prereduction roentgenogram (Fig. 6-A) gave no indication of the degree of rotation of the upper radial fragment. The tuberosity view on the fractured side (Fig. 6-B) corresponded with the 150-degree

view on the calibration chart (Fig. 6-C). The corresponding view on the normal side showed a slightly greater prominence of the tuberosity (Fig. 6-D), and the corrected rotational position was estimated at 140 degrees. The fracture was reduced by traction and manipulation, and immobilized with the wrist at 140 degrees. Satisfactory reduction was obtained (Figs. 6-E and 6-F).

CASE 3. Sepoy N. K. was admitted with a recent fracture of the radius and ulna in the middle third (Fig. 7-A). A tuberosity view on the fractured side corresponded with the 150-degree view on the calibration chart (Figs. 7-B and 7-C). The tuberosity view on the normal side with the wrist at 150 degrees corresponded exactly (Fig. 7-D). Satisfactory reduction and immobilization were carried out with the wrist at 150 degrees (Figs. 7-E and 7-F).

FIG. 5-A

FIG. 5-B

FIG. 5-C

FIG. 5-D

FIG. 5-E

FIG. 5-F

Fig. 5-A: Case 1. Before reduction.
Fig. 5-B: After the first reduction, with the wrist at 90-degree rotation.
Fig. 5-C: Tuberosity view on the fractured side.
Fig. 5-D: Tuberosity view on the normal side with the wrist at 135 degrees.
Fig. 5-E: Post-reduction anteroposterior roentgenogram with the wrist at 130 degrees.
Fig. 5-F: Post-reduction lateral roentgenogram with the wrist at 130 degrees.

Figs. 6-A—6-F (See page 377).

Fig. 6-A: Case 2. Before reduction.
Fig. 6-B: Tuberosity view on the fractured side.
Fig. 6-C: 150-degree tracing from the calibration chart.
Fig. 6-D: Tuberosity view on the normal side with the wrist at 150 degrees.
Fig. 6-E: Post-reduction anteroposterior roentgenogram with the wrist at 140 degrees.
Fig. 6-F: Post-reduction lateral roentgenogram with the wrist at 140 degrees.

FIG. 6-A

FIG. 6-B

FIG. 6-C

FIG. 6-D

FIG. 6-E

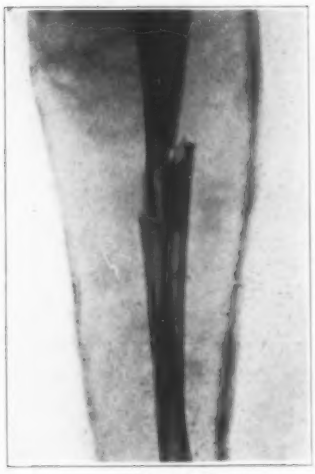

FIG. 6-F

FIG. 7-A

FIG. 7-B

FIG. 7-C

Fig. 7-A: Case 3. Before reduction.
Fig. 7-B: Tuberosity view on the fractured side.
Fig. 7-C: 150-degree tracing from the calibration chart.

The method may also be used to determine the degree of rotational error in united fractures. A tuberosity view is taken of the fractured arm with the hand in the mid-position. This is examined on the calibration chart and an estimation of the rotational deformity is made. A tuberosity view of the normal side is taken to confirm the degree of deformity, and the latter is compared with the limitation of movement noted clinically.

FIG. 7-D

FIG. 7-E

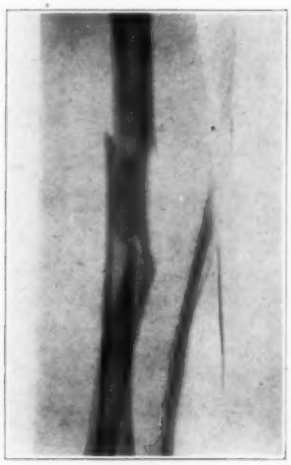

FIG. 7-F

Fig. 7-D: Tuberosity view on the normal side with the wrist at 150 degrees.

Fig. 7-E: Post-reduction anteroposterior roentgenogram with the wrist at 150 degrees.

Fig. 7-F: Post-reduction lateral roentgenogram with the wrist at 150 degrees.

Fig. 8-A: Case 4. Old united fracture of the radius and ulna in the middle third.

Fig. 8-B: Lateral view.

Fig. 8-C: Tuberosity view on the fractured side with the wrist at 90 degrees.

Fig. 8-D: 150-degree tracing from the calibration chart.

Fig. 8-E: Tuberosity view on the normal side with the wrist at 150 degrees.

FIG. 8-A

FIG. 8-B

FIG. 8-C

FIG. 8-D

FIG. 8-E

CASE 4. Major B. had sustained a fracture of the radius and ulna in the middle third, twenty-two years previously (Figs. 8-A and 8-B). A tuberosity view on the fractured side with the wrist at 90 degrees corresponded with the 150-degree view on the calibration chart (Figs. 8-C and 8-D). This was confirmed by a tuberosity view of the normal elbow with the wrist at 150 degrees (Fig. 8-E). The fracture had, therefore, been allowed to unite in a position of rotational deformity of 60 degrees on the pronation side, and limitation of supination of 60 degrees was to be expected. Clinically the patient showed limitation of supination of 70 degrees, his range of rotation being 0 to 110 degrees.

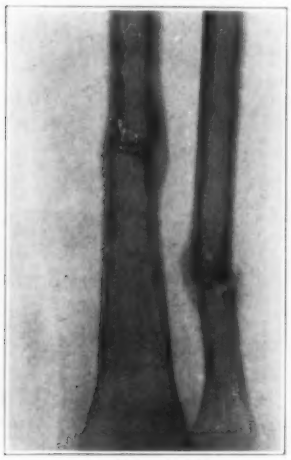

FIG. 9-A

FIG. 9-B

FIG. 9-C

Fig. 9-A: Case 5. Old united fracture of the radius and ulna in the lower third.

Fig. 9-B: Tuberosity view on the fractured side with wrist at 90 degrees.

Fig. 9-C: 120-degree tracing from the calibration chart.

Fig. 9-D: Tuberosity view on the normal side with the wrist at 120 degrees.

CASE 5. L/Cpl. V. had suffered fracture of the radius and ulna in the lower third six months previously (Fig. 9-A). A tuberosity view of this united fracture (Fig. 9-B) with the wrist at 90 degrees lay between the 120-degree (Fig. 9-C) and the 90-degree views on the calibration chart, and corresponded with the tuberosity view of the normal wrist at 120 degrees (Fig. 9-D). Union had taken place with a rotational deformity on the pronation side of 30 degrees, and limitation of supination of 30 degrees was to be expected. Clinically, the patient had limitation of supination of 30 degrees and limitation of pronation of 45 degrees, his range of rotation being 45 to 150 degrees.

FIG. 9-D

SUMMARY

1. A method is described whereby the correct rotational position in which to immobilize a fracture of both bones of the forearm may be determined.

2. All the fractures illustrated, which include fractures of the upper and lower thirds, show a rotational position well on the supination side of the mid-position.

3. The method may also be used to determine the degree of rotational error in united fractures.

Though no conclusions can be drawn from such a small number of cases, and under Active Service conditions a large series is difficult to obtain, the writer believes that all such fractures should be immobilized in some degree of supination.

My thanks are due to Colonel P. J. Jory, D.S.O., Royal Army Medical Corps, for permission to publish this paper, and to Captain G. K. Rose, Royal Army Medical Corps, for his assistance in its compilation.

AN OPERATION FOR PARALYSIS OF THE SERRATUS ANTERIOR

BY DONALD C. DURMAN, M.D., F.A.C.S., SAGINAW, MICHIGAN

Isolated paralysis of the serratus anterior is rather rare, and orthopaedic surgeons are, therefore, seldom faced with the problem of its treatment. However, when treatment is indicated, certain serious objections are inherent in most of the previously reported methods.

The ideal procedure in treatment of serratus anterior paralysis is one which restores scapular movement as opposed to immobilization of the scapula. In other words, the ideal goal is the correction of the deformity without the sacrifice of function of another part from which a muscle or a tendon might be transplanted.

To meet these requirements, and to overcome the objections to the older methods, the following operative procedure was devised in 1939. It has been employed in two instances with such satisfactory results that it is described in the hope that others may be encouraged to follow the procedure and report the results.

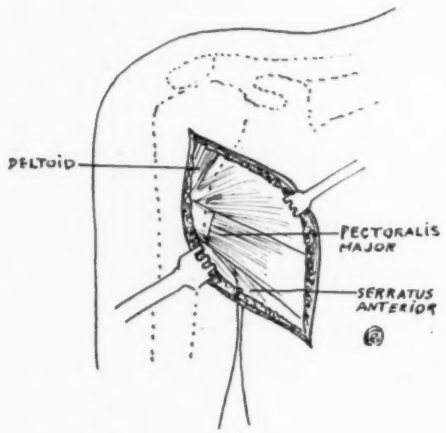

FIG. 1-A
Anterior incision.

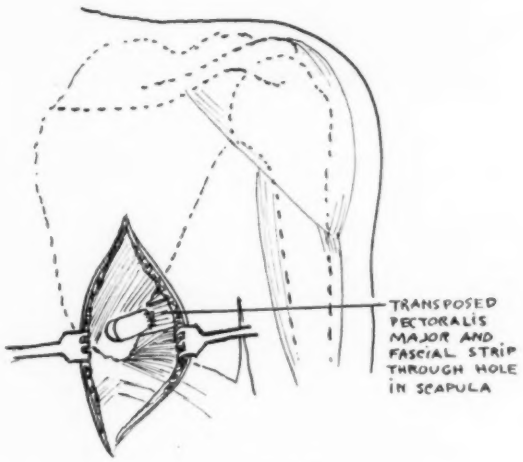

FIG. 1-B
Posterior incision.

OPERATIVE TECHNIQUE

With the patient lying on the sound side, the back and front of the chest on the affected side and the arm and shoulder are prepared. It is important that the arm be freely movable and unencumbered by drapes.

An incision is made, extending from the anterior margin of the deltoid, and the point where it crosses the inferior edge of the tendon of the pectoralis major, along the anterior axillary fold to the chest wall (Fig. 1-A). The upper skin flap is retracted to expose about one-third of the anterior surface of the pectoralis major. The lower one-third of this muscle is split from the upper two-thirds from the chest wall to the humerus, and the tendon of insertion of this lower third is divided close to the bone. This portion of the muscle is freely mobilized.

A longitudinal incision, about four inches long, is then made over the inferior angle of the scapula, the arm being in abduction. The posterior surface of the angle of the scapula is exposed subperiosteally, and a hole is drilled through the bone and enlarged to about one-half an inch in diameter (Fig. 1-B).

While these procedures are being carried out, a second operating team removes a

strip of fascia lata, about six inches long and three inches wide. The length of this graft can be determined by measuring the distance between the tip of the scapula and the severed tendon of the pectoralis major, always allowing sufficient length to permit suturing of the graft to the tendon and looping through the hole which has been drilled in the scapula. The graft is then rolled around the tendon of the pectoralis major to form a tube of several layers' thickness and overlapping the tendon about one inch. It is then securely sutured with silk. The edge of the fascial tube is also sutured upon itself with a running stitch. It is important that the gliding surface of the fascia be also the gliding or superficial surface of the fascial tube. This tube is then passed from the anterior incision through a subcutaneous tunnel to the posterior longitudinal incision over the tip of the scapula. It is looped through the hole in the scapula, pulled taut, and sutured upon itself. During all of this procedure, the scapula should be held depressed against the chest wall and rotated anteriorly. All incisions are closed in the usual way. The arm is immobilized at the side by strips of adhesive tape or a Velpeau bandage. Cautious motion may be started in three weeks.

CASE REPORTS

CASE 1. G. R., male, twenty-three years old, was first seen in December 1939 with a history of pain in the region of the right shoulder in June 1938. When seen, his only complaint was one of fatigue in the shoulder and arm. Physical examination showed the boy to be in good condition, except for the right shoulder which revealed the usual objective findings of a paralyzed serratus anterior, with marked winging of the scapula. All other muscles of the shoulder girdle and upper extremity were functioning normally. Reflexes were normal. A diagnosis of residual deformity from infantile paralysis was made.

The operation as described was performed upon this patient. He made an uneventful recovery, and was discharged from the hospital in five days. Three weeks later the immobilizing dressing was removed, and gentle motion, both active and passive, was started. At that time, the transplanted pectoralis major could be felt to contract strongly on voluntary effort, and a firm cord representing the fascial graft could be seen and felt, running transversely across the axilla to the tip of the scapula. The patient was seen at intervals for several months, and when last seen, scapular movement was normal. The right scapula was slightly more prominent than the left, but was not as conspicuous as it had been. The graft and transplant were functioning excellently. The patient returned to work, and

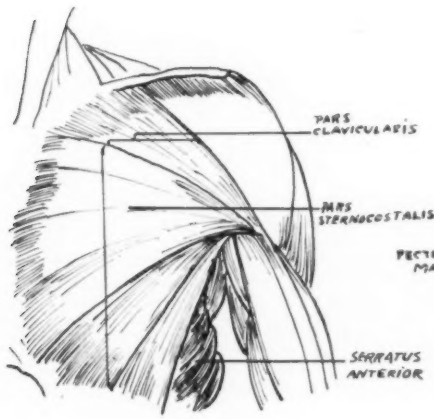

FIG. 2-A

Anterior surface of the chest with muscles intact, to show direction of fibers of pectoralis major.

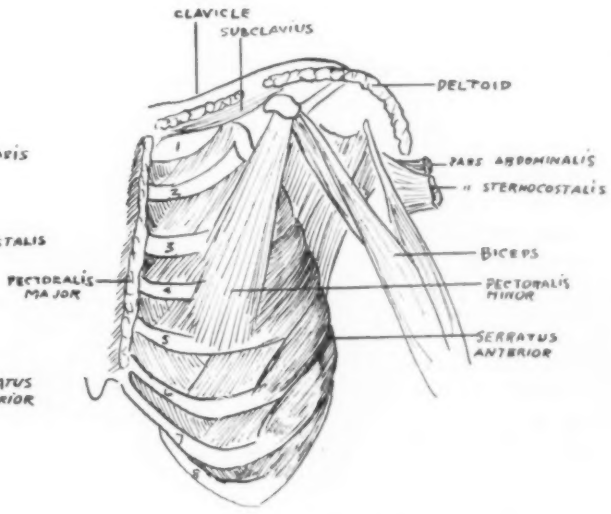

FIG. 2-B

Anterior chest wall with pectoralis major removed, to show the fibers of the serratus anterior and of the pectoralis minor.

it is interesting to note that he later passed the physical examination for the Navy, and has served throughout the War.

CASE 2. A. N., female, twenty-eight years old, was first seen in January 1942. She complained of a prominent right shoulder blade which was cosmetically embarrassing. The patient had had infantile paralysis in childhood. Examination was negative except for the prominent right scapula and loss of power in reaching forward, indicating paralysis of the serratus anterior. Evidence of any central nervous disease was lacking. The patient was operated upon, and kept under observation for six months. The scapula was held close to the chest wall and was nearly normal in movement. The cosmetic result was satisfactory.

A procedure similar to the one described and based upon essentially the same principles was reported by Tubby in 1904. He inserted "the cut end of the pectoralis major into as much of the width of the serratus magnus as possible, and this was done by dividing the cut end of the pectoralis into several fasciculi, then, drawing the paralysed serratus well forward, the fasciculi of the pectoralis were firmly stitched with silk to the serratus magnus over an area corresponding to four or five of the digitations of the latter". The objection to this procedure is the dependence of the pull of the transplanted pectoralis major on a paralyzed, atrophic serratus, which might easily be stretched. While the immediate result of the operation might be satisfactory, the late result might reasonably be expected to be unsatisfactory. (After this paper had been submitted to *The Journal*, the author learned that Ober had operated on two cases, using a procedure similar to that here described by the author.) Dickson has described the use of a fascial transplant from the inferior border of the pectoralis major to the inferior border of the scapula. This would immobilize the lower angle of the scapula, but would probably produce little scapular motion. Whitman fastens the vertebral border of the scapula to the spinous processes of the fourth, fifth, sixth, and seventh thoracic vertebrae by strips of fascia lata.

The operation described fulfills the requirements for such a procedure. The utilization of a portion of the pectoralis major as a substitute for a paralyzed serratus anterior is logical, since the pull of the two muscles is parallel (Fig. 2-B). The pectoralis major abducts and draws the arm forward, and the serratus draws the scapula forward. One should expect the transplanted pectoralis to have little difficulty in becoming adapted to its new function. Lastly, the normal function of the arm and shoulder which is seen following radical mastectomy, in which both pectoral muscles are removed, leads to the conclusion that a portion of the pectoralis major can be sacrificed as an adductor of the arm without interfering with the function of the arm.

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THE TREATMENT OF NON-UNION OR DELAYED UNION OF FRACTURES BY MEANS OF MASSIVE ONLAY GRAFTS FIXED WITH VITALLIUM SCREWS *

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The almost universally good results obtained by means of the massive onlay graft for delayed union or non-union of long bones may well be stressed at this time. However, apart from minor variations in technique, there is nothing new or original in this report.

In essence, the massive onlay graft is simply a full-thickness piece of cortex of autogenous bone applied to the surface of the fragments (across the ununited gap) but not countersunk into the recipient fragments. Union takes place between the fragments and the graft, and directly across the gap. Firm fixation is provided, which is essential.

The inlay or countersunk graft first came into general use about 1912, and since then the technique has been variously modified. For about fifteen years, it was the usual practice to prepare a specially cut bed for the reception of the bone graft—the inlay method. Then in 1927, with the publication of "The Onlay Graft in the Treatment of Ununited Fractures in Long Bones", by Campbell, and, in 1928, the article by Henderson, a new technique came into prominence. From that time on, various authors have described and perfected the onlay graft.

Different methods of fixation of the onlay graft have been suggested,[10,13,17] including aluminum, bronze and silver wire, and kangaroo tendon. With the use of these the author is not in sympathy. Miller reported the technique of onlay and inlay grafts, using removable Kirschner-wire fixation, but the risk of infection in this procedure is obvious. Bone pegs were also used, but they greatly increase the difficulty of the operation.

Vitallium screws have greatly simplified the procedure of bone grafting. Their use is now widespread in the United States and Canada and in the British Isles, and after six years there are no reports of their having had any detrimental effects on body tissues. Vitallium is sufficiently passive in body fluids to resist disintegration, and it does not release metallic ions into the tissues. It appears to be completely inert. It is extremely strong and hard. On occasion, when a plate or screws have had to be removed, they have always been found to have retained their high polish, and no harmful effects have been noted in the adjacent tissues.

FUNCTION OF A BONE GRAFT

A bone graft has at least two functions,—(1) it must provide a rigid internal fixation, and (2) it must play a physiological rôle. The graft can hardly be regarded as a "dead strut", otherwise simple plating would produce the desired effect. This might be illustrated by the fact that fractures of the neck of the femur, with the fracture line at more than 60 degrees to the horizontal plane, will not unite when transfixed by a Smith-Petersen nail unless the use of the nail is supplemented by a bone graft. Hey Groves upheld the theory of the living graft, as did Lambrinudi and Stamm. Further weight might be added to the theory of the physiological rôle by a recent personal communication from Major H. C. Blair, Medical Corps, Army of the United States, who has been applying his onlay grafts cortex to cortex, and has been gratified by the rapidity of union obtained.

Whatever the underlying principles may be, it would seem that the massive onlay

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graft, fixed with vitallium screws, met all the requirements,—internal fixation, supplementary bone, osteogenic material, and the stimulation of osteogenesis.

RESULTS

In some 170 cases in which this method of grafting the long bones has been employed, the author has had only one failure, an old ununited fracture of the upper end of the tibia, which united successfully after a second similar graft.

This report is based on only thirty cases, of which accurate case records have been kept in the Orthopaedic Service of the Royal Air Force. A period of about two years is covered. In all, the bones grafted have united in good position. Seventeen of the patients are on full duty at their various air or ground assignments. Three are on limited service, including non-operational flying. One, who had a forearm graft and later a mid-thigh amputation, is unfit for flying. One, who had grafts of both femur and tibia, is undergoing treatment for a sciatic lesion dating from the injury. Two have been discharged from the service, and the remaining six are still undergoing rehabilitation. The site of graft and average time of fixation for this series, treated in England, are shown in Table I.

TABLE I

FRACTURES OF LONG BONES TREATED WITH ONLAY GRAFTS

Site of Fracture	Number of Cases	Average Period of Fixation
Radius	8	10 weeks
Ulna	4	10 weeks
Femur	6	4 months
Tibia	11	4 months
Humerus	1	11 weeks

The age incidence was favorable, nineteen to thirty-six, with the exception of one patient fifty-seven years old, with fractures of the forearm, in whom bone was produced at an incredible rate. Thirteen of the patients suffered fractures as the result of aircraft accidents; fifteen as the result of motorcar or motorcycle accidents; one was due to a bomb explosion; and one was the result of football injuries. Nine of the patients were under treatment on this Service from the onset of injury, while the remainder had been treated elsewhere for periods varying from one month to a year. Complications, such as skin loss, frostbite, compound wounds, and burns, were contributing factors to the delaying of union or to the malposition of fragments.

OPERATIVE TECHNIQUE

A tourniquet is used wherever possible, even in grafts of the femoral shaft. In the latter case a Steinmann pin is passed from front to back just above the greater trochanter and just inside the iliotibial band. The tourniquet is then applied around the groin and above the pin. In operations on the forearm and leg, pneumatic tourniquets are by far the most satisfactory; in the arm, pressure should be about 240 millimeters (Bunnell advises 300 millimeters). In the Campbell-Boyd type of pneumatic tourniquet, the pressure is maintained for the arm at nine pounds, and for the leg at fourteen. In the lower extremity a tourniquet applied below the upper third of the thigh is dangerous.

The operation is greatly facilitated by having two teams working, one preparing the bed for the graft and securing it in position, while the other obtains the graft. A tibial graft is decidedly preferable because it is strong enough to impart rigid internal fixation.

The Approach

The approach to the shafts of the long bones must be definitely along anatomical planes. The work of Henry on this subject is classic. No exposure of a long bone should

be made without due respect for soft tissues. The result of surgical trauma to normal structures may be serious; its avoidance cannot be stressed too strongly.

Preparation of Fragment Ends and Graft Bed

All fibrous tissue intervening between the fragments and all excess callus should be removed. Disturbance of normal periosteum should be kept to a minimum. The ends of the fragments should be freshened by removal of sclerotic bone and the medullary canals opened by drilling, if necessary. Care in properly fitting together the ends of the fragments is essential.

It is usually unnecessary to section the fibula in grafting the tibia; occasionally this has to be done. When a gap of half an inch, bridged by one or two massive onlay grafts, can be packed with osteogenic material from the medullary canal at the upper end of the tibia, supplemented by small bone chips, union may be expected. In such a case the impression of a gap may be given in the postoperative roentgenogram; actually there is no gap.

When the fragments have been accurately apposed, a bed is prepared. This is done most easily by a chisel, rather than by an osteotome. In all long bones except the tibia, the bed is prepared on the most easily available surface, having regard to such structures as the musculospiral nerve in the humerus. In the tibia, it is made over the lateral aspect of the bone. In this site the graft is covered by the extensor-muscle bellies; when placed on the flat anteromedial aspect, it is virtually subcutaneous.

Preparation of the Graft

It is preferable to select the upper end of the tibia for grafts, since in this area they seem more osteogenic. Furthermore, the nutrient artery is avoided as well as the possible subsequent development of a hematoma. Another advantage is that it provides easy access to the upper part of the medulla, the source of the semifluid cancellous material which may be easily pressed into every crevice at the recipient site. The iliac crest, probably the ideal bone graft from an osteogenic standpoint, is too malleable for this purpose.

The graft is removed from the donor tibia by the use of an electric saw. Before the graft is removed, it is helpful to bevel its edges and place the drill holes. The medullary portion of the tibial graft is removed from the cortical portion by means of a broad osteotome, the graft being firmly held, edge up, on a wooden block by an assistant. This leaves a rough contact surface.

Application of the Graft

The medullary portion of the graft is placed easily in the prepared medullary canal and the cortical portion settled in the prepared bed. After the recipient fragments have been drilled, the graft is fixed in position by means of vitallium screws of suitable length. Six screws are usually used in all but forearm grafts (where four usually suffice). Six screws give twice the stability obtained by four. The screws are "staggered", thus ensuring against torsion strain. The screws must engage both cortices of the recipient fragments. The graft can be fastened to the fragments advantageously from the uppermost drill hole downward, being held in contact with the fragments quite easily by means of one or two Lane bone holders. When the distal fragment is reached, it can be accurately apposed to the graft and maintained while it is being engaged.

Finally, all crevices are filled with material scooped from the medulla of the donor leg, the material being used like mortar. The wounds are sutured with interrupted nylon in the skin, and a padded plaster cast is applied. After fourteen days, this cast and the sutures are removed, and a non-padded cast is substituted. At the same time the sutures are removed from the donor leg and a long non-padded cast is applied. This may be

changed to a below-the-knee cast at the end of seven or eight weeks, and at the end of another four weeks a walking heel may be added. Protection for ten weeks should suffice for the donor leg, while fixation of the grafted limb in plaster is maintained until union is clinically and roentgenographically solid.

The period of external fixation found to be necessary in this series (in England) is shown in Table I.

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CORRECTION OF HALLUX VALGUS BY METATARSAL OSTEOTOMY

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Since 1922, the standard procedure at the Henry Ford Hospital for the correction of hallux valgus deformities has evolved from the original osteotomy operations devised by Hohmann and Peabody. Over a period of years several modifications of the original procedures have been adopted to improve the technique, and to correct more completely the underlying causes of the deformity.

In 1923, Hohmann reported for the first time an osteotomy operation devised for the correction of hallux valgus. It was a radical departure from the accepted bunionectomies of the time, and, although it was a sound procedure basically, there seemed to remain a number of deficiencies. The operative technique consisted of a trapezoid resection of the metatarsal shaft proximal to the exostosis, followed by reapproximation of the fragments. No attempt was made to remove the exostosis, to visualize the joint, or to excise the bursa. The adductor hallucis tendon was shortened in a further effort to prevent recurrence of the deformity. Stable internal fixation of the metatarsal fragments was not attempted.

Peabody in 1931 reported a bunionectomy, first employed in 1922, which was the forerunner of the operation we shall describe. Notable among the improvements in operative technique over that of the Hohmann operation was the use of a heavy chromic suture for internal fixation. The suture was inserted through drill holes in the apposing metatarsal fragments to prevent shifting during convalescence. Peabody also noted that a bone spicule retained on the lateral aspect of the capital fragment assisted in preventing horizontal shifting of the fragments. Other advances were the excision of the exostosis and the plastic repair of the capsule. The osteotomy employed was uniformly cuneiform, the wedge-shaped bone fragment being removed prior to approximation of the capital and diaphyseal margins. It is the authors' opinion that the theory supporting this type of osteotomy is in error, inasmuch as the basic deformity, the metatarsus primus varus, is not corrected, but is exaggerated by reapproximation of the metatarsal fragments. This would then predispose to recurrence of the deformity. It has been the tendency in the past to underestimate the significance of the congenital varus deviation of the first metatarsal in the development of the typical hallux valgus deformity. Shoes have borne the burden of the blame for many years. This "vicious shoeing" we now realize is of secondary importance, and is rarely capable of producing severe bunions unless the basic metatarsus primus varus already exists. This deformity makes the great toe more vulnerable to extrinsic influences, particularly short stockings and short, narrow shoes, which eventually produce the characteristic deformity.

The Mayo bunionectomy has withstood the test of time, and has acquired a great many enthusiastic supporters. It is essentially an arthroplasty of the metatarsophalangeal joint, which consists of resection of the cartilage-bearing surface of the metatarsal. The head is then remodeled, and a U-shaped bursal flap is turned into the joint. Since the articular cartilage is often uninvolved, we feel that this operation should not be performed indiscriminately, but should be reserved for severe deformities associated with degenerative changes within the joint. The surgical shortening of the first metatarsal is capable of producing a secondary metatarsalgia through the shifting of the burden of weight-bearing toward the lateral aspect of the foot.

The bunionectomy devised by McBride adheres to conservatism, and employs a minimum of bone surgery. Briefly the procedure consists of transplantation of the common

FIG. 1-A

Metatarsus primus varus of 17 degrees. Hallux valgus Grade 3. Note Freiberg's infraction.

FIG. 1-B

Postoperative roentgenogram. Varus deviation of first metatarsal, corrected to 9 degrees.

FIG. 1-C

Correction maintained at 9 degrees after two and a half years.

tendon of the adductor hallucis from the base of the proximal phalanx to the head of the first metatarsal. The external sesamoid is removed, when indicated. The bursa over the medial aspect of the metatarsal head and the exostosis are removed. Manipulation of the great toe into a position of overcorrection, and of the first metatarsal into a more lateral position is followed by application of a corrective plaster slipper. Statistically the results appear to be very satisfactory in the series of patients reported by McBride, who range in age from sixteen to seventy-one years.

It is difficult to conceive that transplantation of the relatively weak adductor hallucis muscle is capable of maintaining the first metatarsal in this more lateral position. It would seem that complete and permanent correction would necessitate an osteotomy of the metatarsal of the type described by Lapidus, or that which the authors will describe. For the sake of simplicity, we prefer the double transverse osteotomy to the formidable reconstruction of the proximal metatarsal shaft, employed by Lapidus.

Indications for the correction of hallux valgus by metatarsal osteotomy are essentially the same as those for other bunion operations. They are valgus deformity of the great toe, painful metatarsophalangeal articulation, exostosis formation, irritation of the bursa, and, more important, the metatarsus primus varus which is always present in more serious cases. In fifty-five of our cases, chosen at random, the average deviation of the first metatarsal from the longitudinal axis of the second was 13.8 degrees. The variation in the group was from 9 to 19 degrees. By means of metatarsal osteotomy it was possible to attain an average correction of 5.2 degrees, or to 8.6 degrees. The range of correction was from 1 to 11 degrees (Figs. 1-A, 1-B, and 1-C).

In another series of cases, which we shall consider normal feet, it was found that the angle of deviation of the first metatarsal varied from 2 to 9 degrees, the average being 5.6 degrees. This group of fifty patients had been under treatment for contusions or fractures of the toes, and none had complained of the symptoms associated with hallux valgus. It is our opinion that the hallux valgus deformity should be corrected by the metatarsal osteotomy in all instances where deviation of the first metatarsal is 10 degrees or more. Conversely, if the deviation is less than 10 degrees, a more conservative bunionectomy will give satisfactory relief from symptoms. In such instances, the basis of the complaint is a large exostosis over the metatarsal head, which gives the erroneous impression of abnormal deviation of the first metatarsal. In situations such as this, we have found that the technique of Silver has given very gratifying results.

Failure to obtain a satisfactory functional and cosmetic result following bunionectomy can be attributed to a great number of inadequacies of technique and errors in judgment. Most important of these are:

1. Failure to remove the exostosis adequately.
2. Damage to the articular cartilage of the involved bones, predisposing to hallux rigidus.
3. Failure to correct the metatarsus primus varus.
4. Alteration of the sesamoid-metatarsal relationship.
5. Excessive shortening of the first metatarsal, thereby altering the ratio of weight distribution. This situation has been described by Morton[9]. The short first metatarsal, whether of congenital or surgical origin, predisposes to metatarsalgia through the shifting of the weight from the first metatarsal to the heads of the second and third.
6. Failure to shorten the tibial collateral ligament.
7. Failure to employ corrective dressings for a sufficient period of time after operation.
8. Wearing of improper shoes after surgical correction.

The writers carefully observe the above precautions in performing the correction for hallux valgus, as will be evident in the detailed description of the surgical technique and after-care.

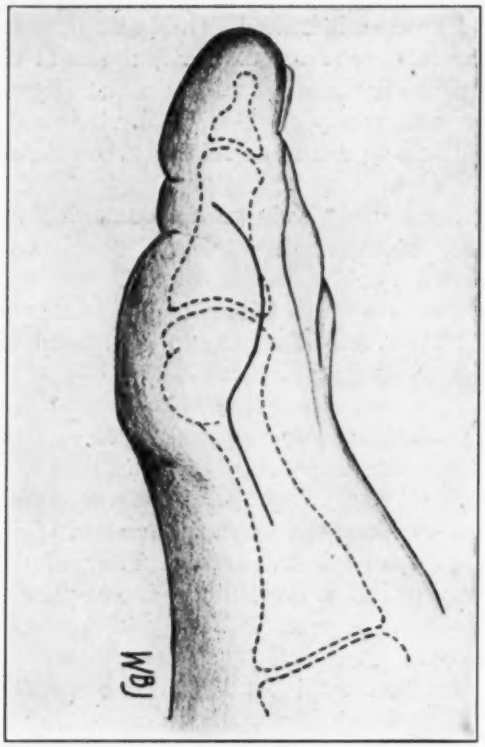

FIG. 2

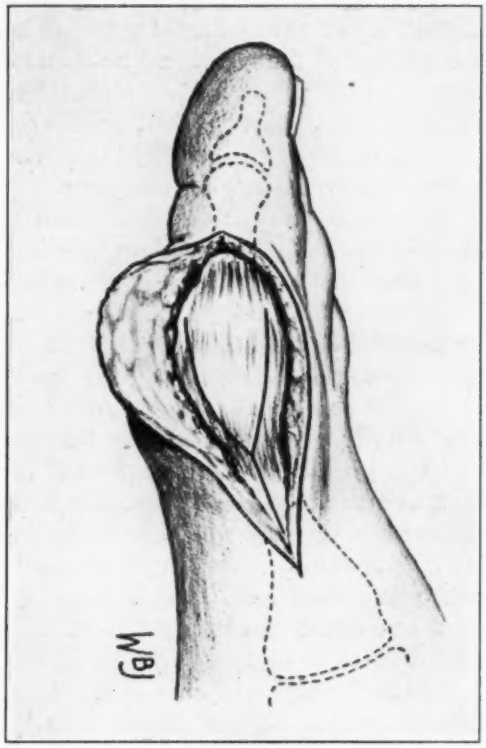

FIG. 3

FIG. 4

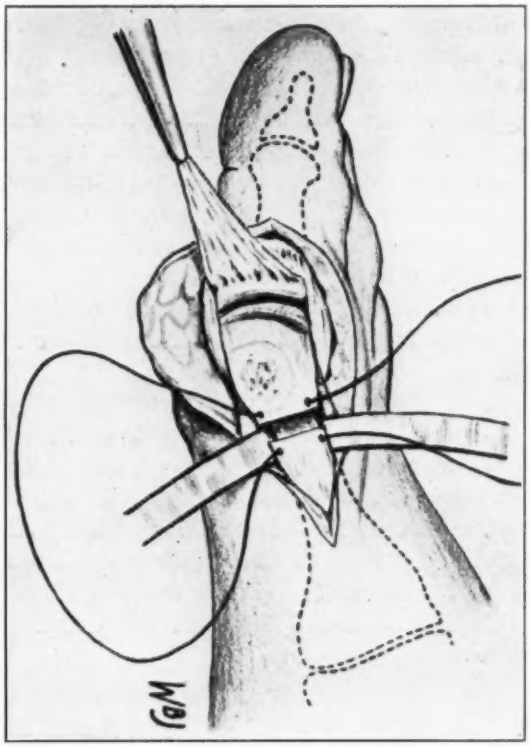

FIG. 5

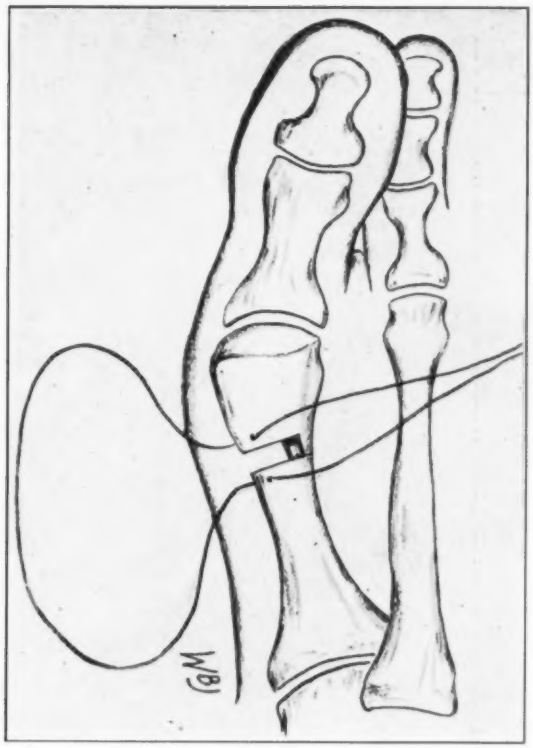

FIG. 6

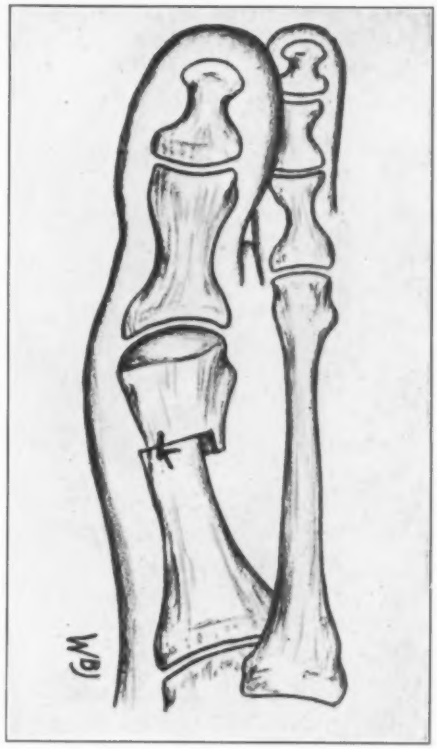

FIG. 7

OPERATIVE TECHNIQUE

1. Two routine orthopaedic preparations are required during the twelve hours preceding operation. The feet are again prepared with a suitable antiseptic in the operating room.

2. An Esmarch tourniquet is applied to the lower leg, extending to approximately four inches below the head of the fibula, thereby avoiding injury to the common peroneal nerve.

3. The feet are draped separately, thus enabling two surgical teams to operate simultaneously.

4. A curved skin incision, five to six centimeters in length, is made over the medial aspect of the first metatarsophalangeal joint with the maximum convexity over the joint itself (Fig. 2). This is followed by subcutaneous dissection and reflection of the skin flaps. The bursa may or may not be excised, depending upon the degree of irritative change.

5. A Y-shaped incision is then made through the capsule and periosteum of the metatarsal shaft (Fig. 3). This flap is freed from the shaft, leaving the base attached to the proximal phalanx. The joint and exostosis are then exposed.

6. The exostosis is excised cleanly, flush with the shaft (Fig. 4).

7. Drill holes are placed through the metatarsal shaft in the anteroposterior plane near the medial cortex, about one-half inch apart, the distal perforation being approximately one-half inch proximal to the articular cartilage (Fig. 5). Number 3 chromic suture is then threaded through the drill holes.

8. The metatarsal shaft is then doubly osteotomized perpendicular to the shaft with the power saw (Fig. 6). The interposing fragment, which should not exceed one-eighth of an inch in breadth, is then removed. The proximal osteotomy is completed with saw or bone-cutting forceps, leaving a short spur on the distal fragment. The depth to which the double osteotomy is carried is determined by the degree of metatarsus primus varus

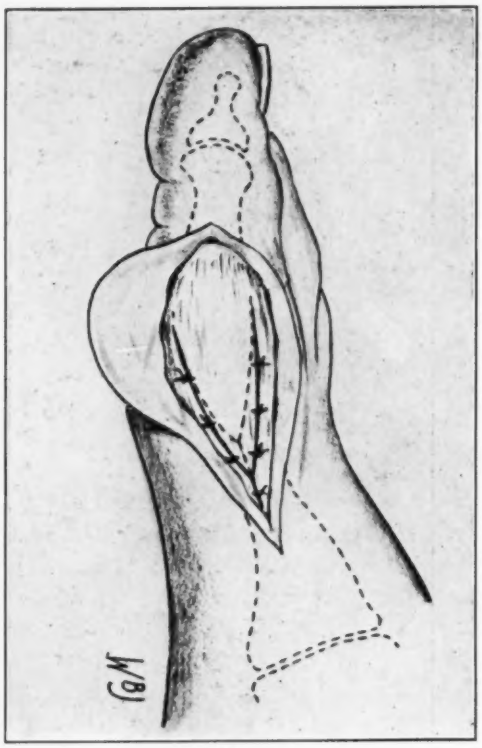

FIG. 8

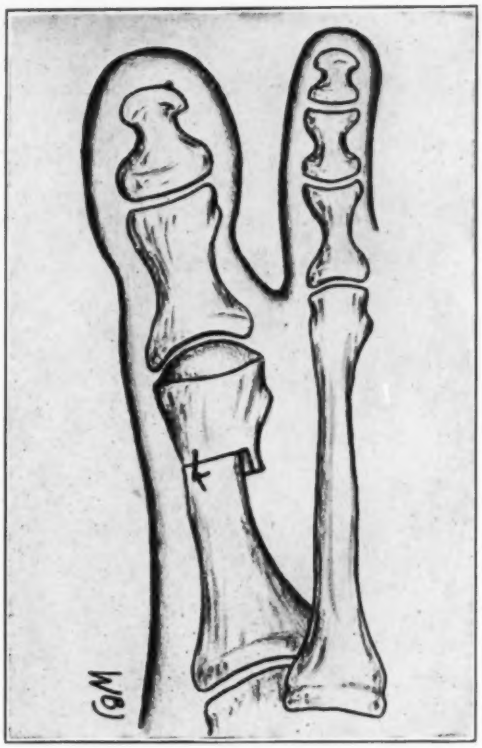

FIG. 9

and the breadth of the foot. In extreme deformities, the grooves penetrate to a depth of approximately one-half the width of the shaft; consequently, upon completion of the proximal osteotomy, a broad spur is left continuous with the distal fragment.

Conversely, if the foot is narrow or the deformity relatively slight, the osteotomy grooves penetrate to the opposite cortex, or approximately five-sixths the width of the shaft. This leaves a narrow spur attached to the distal fragment.

9. The capital fragment is displaced laterally on the proximal, the displacement being maintained by the spur (Fig. 7). The heavy suture is then securely tied, holding the fragments in firm apposition.

10. The great toe is then forcibly abducted and held in slight flexion while a plastic repair is performed on the capsuloperiosteal flap (Figs. 8 and 9). The V-shaped flap is sutured far proximally on the metatarsal shaft to maintain the toe in the overcorrected position. This is followed by the usual closure of the subcutaneous and cutaneous tissues.

Tongue blades are employed as splints on the medial and plantar surfaces, incorporated in the sterile dressing, and secured in place with strips of adhesive. The importance of postoperative care must not be underestimated, and one must be cognizant at all times that there has been a surgical fracture of the metatarsal shaft. We make no effort to disturb the dressing until ten postoperative days have passed, and then only to remove the sutures. Splints are firmly reapplied weekly until five weeks have passed, at which time the patient is ready to wear a straight-last oxford. At this stage, toe posts (Fig. 10) are supplied, which are worn as night splints to prevent direct pressure upon the toes from the bed clothing during this early period. These are worn during the next twelve weeks.

Recently weight-bearing has been permitted four or five days after operation, the patient being encouraged to bear weight on the heels with the aid of crutches. No untoward effects have been noted.

Through close adherence to the technique described, it is possible to correct, both anatomically and mechanically, a painful and disconcerting deformity. The toe is again in alignment with the shaft of the metatarsal which is straightened for the first time. Consequently the foot is somewhat narrower. Normal weight-bearing lines are established, and the patient is again able to walk in the normal heel-toe manner. The sesamoid-metatarsal relationship is not disturbed, nor has the articular cartilage been destroyed. The joint is again made painless through the removal of the exostosis underlying the subcutaneous bursa, which is excised if irritative changes are present.

FIG. 10

There is no possibility of aseptic necrosis of the capital fragments, since only the medial portion of the capsule is incised, thereby preserving adequate vascularity. By performing the osteotomy through the shaft rather than through the cancellous bone of the metatarsal head, surgical trauma to the capital fragment is minimized.

In a recent survey of end-results of bunionectomies performed during the past twenty years, questionnaires were sent to all patients regardless of the type of operation. Prior to January 1944, 188 corrections had been accomplished by metatarsal osteotomy. Since that date twenty-three operations of this type have been performed.

In sixty-four cases where varus deviation of the first metatarsal was not great enough to warrant the more radical procedure, the Silver operation was employed. During the same period, six Mayo and four Keller operations were performed. The average period of postoperative observation was four and one-tenth years. Of all patients, 88.3 per cent. were females, and 11.7 per cent. were males. Ages ranged from fourteen to seventy-seven years, the average age being forty-two years.

The following statistics were compiled from the responses of all patients upon whom the metatarsal osteotomy had been performed prior to January 1944.

The questions and responses are as follows:

1. *Are you satisfied with the results?*

One hundred eighty-two patients (96.8 per cent.) were satisfied.

Four patients (2.1 per cent.) noted some improvement, but were not entirely satisfied. (All of these patients had chronic rheumatoid arthritis.)

Two patients (1.1 per cent.) were dissatisfied. (These patients had subacute rheumatoid arthritis and roentgenographic evidence of gout.)

2. *Has there been a recurrence of the previous deformity?*

One hundred sixty-three patients (86.8 per cent.) had not noticed any recurrence of the deformity.

Eighteen patients (9.6 per cent.) noted slight recurrence of the deformity.

Seven patients (3.6 per cent.) noted marked recurrence of the deformity. (All of these patients were arthritics.)

3. *Is there persistent pain over the great-toe joint?*

One hundred eighty-two patients (96.8 per cent.) were completely relieved of pain over the first metatarsophalangeal joint.

Six patients (3.2 per cent.) had persistent pain over the first metatarsophalangeal joint, ranging from slight to severe.

4. Is there pain over the weight-bearing surface (metatarsals) of the forefoot?

5. Did you have pain over the weight-bearing surface of the forefoot (metatarsals) in addition to the bunion before operation?

From the responses to Questions 4 and 5, we were able to determine that 45.6 per cent. of all patients had some degree of metatarsal pain previous to operation.

Of this group, 60.9 per cent. were relieved completely of discomfort in the metatarsal arch, while 39.1 per cent. noted no change.

Of those who had no metatarsal symptoms before operation, 13.3 per cent. developed pain in the metatarsal arch during the years following.

The other 41.1 per cent. had no metatarsal symptoms, either before or after operation.

These statistics seemed to confirm our clinical impressions and were in general very gratifying. It was somewhat disappointing on the other hand to note that 13.3 per cent. of the patients had developed symptoms referable to the metatarsal arch. This is best explained (1) by the normal aging process with associated vascular changes; and (2) by removal of an excessively wide segment of a congenitally short metatarsal shaft. This technical error has recently been recognized. As a result, the shortened first metatarsal then passively shifts the burden of weight-bearing to the heads of the second and third metatarsals.

It is also to be noted that this type of operation is not particularly successful in arthritics. Our only poor results were encountered in this group of patients. However, reconstructive orthopaedic surgery is in general very discouraging in cases of articular degeneration. It is possible that the Mayo bunionectomy would give better results in arthritics. Our experience with this procedure is not adequate to warrant an opinion.

CONCLUSIONS

In all severe hallux valgus deformities there is a basic metatarsus primus varus which varied from 9 to 13 degrees (in our series). Transverse metatarsal osteotomy is performed to overcome the varus deviation of the first metatarsal. Correction of the hallux valgus is accomplished by plastic repair of the capsuloperiosteal flap. Failure to correct the congenital metatarsal deformity predisposes to recurrence of the "bunion". Excessive shortening of the metatarsal shaft is occasionally responsible for postoperative symptoms of the metatarsal arch. The operation is adaptable to all degrees of deformity. The technique is relatively simple, and the results are uniformly good.

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HEALING TIME IN FRACTURES OF THE SHAFTS OF THE TIBIA AND FEMUR *

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The healing time of the long bones of the lower extremity is notoriously uncertain in adults. It is of particular importance economically to the patient, the family, and the community. As long as weight-bearing is not possible, or is limited, the patient is a liability to himself and his community. Therefore, he is entitled to know, as accurately as possible, how long he will be incapacitated by his fracture. Reasonably accurate prognosis is of great importance in the teaching of students, and in advising the patient, and the insurance company in case of industrial accident. The estimate should, of course, be based on the factors which influence healing,—such as (1) the amount of contusion, comminution, and compounding, (2) the type of fracture, (3) the site of the fracture, (4) the age of the patient, and (5) the method of treatment.

Textbooks by Key and Conwell, Caldwell, Scudder, Lewin, Böhler, Magnuson, Compere and Banks, and Kellogg Speed are at variance on this subject, and tend to underestimate the approximate time of healing. The belief that such fractures do not heal as rapidly today as formerly, as suggested by McMurray, is unfounded, as demonstrated by Watson-Jones and Coltart, and by Young and Blaisdell.

The authors agree with these investigators that distraction, infection, angulation, and disturbance of blood supply (which includes remanipulation) are the most important adverse factors in non-union and delayed union.

Age

In our series of 256 cases there has been no case of non-union in children under fifteen years of age, with the exception of congenital fracture of the tibia. One case of delayed union was encountered in a compound fracture with severe comminution. Youth is an assuring element in the healing of fractures. There are few factors which can prevent the union of any bone in children. There may be malunion with overriding or angulation, but, unless there is interposition of tissue or complicating pathological changes, non-union does not exist. For this reason, all patients under fifteen years of age are eliminated from these statistics of healing time. There seems to be no great difference in the percentage of delayed union or non-union in patients beyond the growing period, whether the fracture be in a person twenty-one or ninety-one years of age.

Blood Supply

Variation in the healing time occurs in all types of fractures, but the variation in healing of fractures of cancellous bone is so much less than in fractures of cortical bone that one may well assume that blood supply is the most important factor of all elements influencing healing. This is further substantiated by experience with fractures of the neck of the femur. Fractures of the femoral shaft rarely go on to non-union, although they are often prone to delayed union. One patient, showing non-union at the end of two years and refusing further treatment, returned at the end of five years with complete union, but with the characteristic deformity of outward bowing of the thigh and inward rotation of the lower fragment. The factor of blood supply is especially important in fractures situated where there is little surrounding vascular tissue, and consequently limited blood supply. This situation is found in the lower half of the tibia, and in this region there is a large percentage of delayed union and non-union.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

TABLE I

FRACTURES OF THE TIBIA AND FIBULA

Group	Average Healing Time								
	For All Cases*			In the Third of the Cases First to Unite		In the Third of the Cases Last to Unite		Cases Uniting in Less than 24 Weeks	
	No. of Cases	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Authors' Series (*Per Cent.*)	Series of Watson-Jones and Coltart (*Per Cent.*)
1. Reduction: continuous plaster fixation	46	12	21	8.5	13	16	24	78	95
2. Reduction by traction, later plaster fixation	40	19	29	10.0	16	25	25	50	74
3. Distraction or other separation of fragments	3	16	26	—	—	—	—	33	31
4. Compound, not infected	10	18	24	7.0	13	23	26	70	72
5. Infected, all causes	11	26	40	—	—	—	—	27	35
All groups	110	18	28						

*The average hospital stay for all patients with fracture of the tibia and fibula was twelve days.

TABLE II

AVERAGE HEALING TIME IN REGARD TO LOCATION OF TIBIAL FRACTURE

Location	No. of Cases	Clinical Union	Union Shown by X-Ray
Lower third	39	16 weeks	25 weeks
Junction of middle and lower thirds	16	19 weeks	29 weeks
Middle third	39	18 weeks	29 weeks
Junction of upper and middle thirds	2	15 weeks	29 weeks
Upper third	14	14 weeks	18 weeks

TABLE III

AVERAGE HEALING TIME FOR DIFFERENT TYPES OF FRACTURES OF THE TIBIA AND FIBULA

Type of Fracture	No. of Cases	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)
Transverse	8	14	21.0
Oblique	28	16	22.0
Spiral	14	12	19.5
Comminuted	60	19	30.0
Compound	32	23	34.0

METHOD OF TREATMENT

In view of the experience with our own cases and with those patients who have come to us from elsewhere, we feel that nature will do a great deal, if given a reasonable chance by the preservation of length and alignment, and by the restoration of function. The outcome will be better with conservative methods, as far as the healing time, the comfort of the patient, and the end result are concerned; certainly the chance of complication is much less. There are serious dangers in radical treatment, but one must admit the necessity and advantage of certain forms of internal fixation in selected cases. Undoubtedly there are many patients who have suffered the effects of radical treatment in inexperienced hands. The authors believe in the use of internal and external skeletal fixation of fractures as an unavoidable necessity in certain cases, rather than as a routine method of choice. Its use in no way speeds the time of union of the fracture, and often delays it. Skeletal fixation is necessary when it is impossible to hold the fragments in position in any other way; its employment usually means quicker evacuation of the patient from the hospital. However, in all cases, continued and, if necessary, prolonged immobilization is urged; and early weight-bearing, regardless of mechanical fixation, should be discouraged. It should be noted that our observations are not based upon our own experience with respect to skeletal fixation, but upon the results noted by us in referred cases treated by others.

RESULTS

The series of cases considered and tabulated here includes 149 consecutive cases of fracture of the tibia and fibula, and 107 cases of fracture of the femoral shaft. They were practically all among civilians, rather than war injuries.

Twenty-five cases of fracture of the tibia and fibula have been eliminated, because the patients were under fifteen years of age; the average age was nine and a half years, and the average healing time was seven and a half weeks. Thirty-six cases of fracture of the shaft of the femur have also been eliminated, because the patients were under fifteen years of age; the average age of this group was six years, and the average clinical healing time was four weeks. The average time of healing, as shown by roentgenogram, for all groups was nine weeks.

Fourteen adult patients were eliminated from each group because of (1) failure to return for final observation, (2) amputation, or (3) death resulting from fracture or other complications. There remain for further analysis 110 cases of fracture of the tibia and fibula, the average age of these patients being forty-one years, and fifty-seven cases of fracture of the shaft of the femur, the average age of the patients being forty-two years.

Clinical healing was determined by the lack of any evidence of mobility on manipulation and by the presence of palpable callus about the site of the fracture. Roentgenographic evidence of union was determined by the presence of complete connective callus between the ends of the fragments.

The grouping used in this analysis is that employed by Watson-Jones and Coltart.

Group 1. Those cases in which immobilization was continuous. Casts were removed intermittently only for roentgenographic interpretation of progress.

Group 2. Cases where traction was used as a primary measure and plaster casts were later applied.

Group 3. In these cases, traction or manipulation led to the separation of the fragments to the extent of one-eighth to three-eighths of an inch.

Group 4. Compound fractures, either of the minor or major types, without infection.

Group 5. Definitely infected fractures (which included those reaching treatment after the safety period), those secondary to débridement, and those having delayed infection.

TABLE IV

FRACTURES OF THE SHAFT OF THE FEMUR

Group	Average Healing Time								
	For All Cases			In the Third of the Cases First to Unite		In the Third of the Cases Last to Unite		Cases Uniting in Less than 24 Weeks	
	No. of Cases	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Authors' Series (*Per Cent.*)	Series of Watson-Jones and Coltart (*Per Cent.*)
1. Reduction: continuous plaster fixation	39	9.5	20	6	13	13	25	75.0	95
2. Reduction by traction, later plaster fixation	9	8.0	20	6	13	10	25	63.5	64
3. Distraction or other separation of fragments	2	9.5	31	—	—	—	—	—	—
4. Compound, not infected	1	18.0	44	—	—	—	—	—	—
5. Infected, all causes	3	11.0	37	—	—	—	—	—	—
All groups	54 *	11.2	30.4						

* Not including two cases of non-union and one that did not heal for 148 weeks.

TABLE V

AVERAGE HEALING TIME IN REGARD TO LOCATION OF FEMORAL FRACTURE

Location	No. of Cases	Union Shown by X-Ray
Lower third	14	18 weeks
Middle third	24	21 weeks
Upper third	16	25 weeks

TABLE VI

AVERAGE HEALING TIME FOR DIFFERENT TYPES OF FRACTURES OF THE SHAFT OF THE FEMUR

Type of Fracture	No. of Cases	Union Shown by X-Ray (*Weeks*)
Transverse	13 (1 non-union)	19.0
Oblique	15	23.5
Spiral	1 (non-union)	—
Comminuted	26	22.5
Compound	6	23.5

Fractures of the Tibia and Fibula

The results obtained in fractures of the tibia and fibula are shown in Table I, which includes a comparison of our results with those of Watson-Jones and Coltart.

The healing time, in relation to the location in the tibia, is shown in Table II.

Whether the fracture was comminuted, transverse, oblique, spiral, or compound seemed to make very little difference in healing time, although the comminuted and compound fractures averaged a little longer (Table III).

Fractures of the Shaft of the Femur

The results obtained in fractures of the shaft of the femur are shown in Table IV.

Internal fixation was not used in any of our cases. Pin and bar fixation was used in only one. Russell traction was the most effective means of obtaining a good result, and it was used in all cases where manipulative reduction could not be accomplished. Its drawbacks are the time and patience required, and its necessities are plenty of good moleskin adhesive and constant watching. Many poor results can be obtained by any method, if doctor and patient forget these elements or compromise upon them. The callus may be too little, and the time not late enough.

The average hospital stay for patients with fracture of the femur was fifty-four days. The average stay for forty-six adults in traction was seventy-three days. The average stay for eight patients in skeletal traction was sixty-eight days. (For thirty-three children in traction, the average stay in the hospital was forty and six-tenths days. Two children in skeletal traction remained an average of fifty-six days.)

Fractures of the lower third of the shaft of the femur seemed to heal more rapidly than those in the middle and upper thirds. The upper third was the slowest to heal and the most difficult to manage, in spite of the fact that it was never possible to create distraction in this area (Table V).

In Table VI an analysis is made of the time element in healing of fractures of the femur in relation to their anatomical and physical types. Transverse, oblique, spiral, comminuted, and compound fractures are considered.

CONCLUSIONS

1. The long bones of the lower extremity are the biggest and strongest bones in the body. The force required to break them must necessarily be great, and the damage taking place at the time of injury is not only in the bone, but in the surrounding tissues. The speed of healing of fractures is usually proportionate to the amount of available circulation to and between the fragments.

2. In spite of the foregoing deduction, all the causes of delayed union and of non-union have not yet been determined.

3. The percentage of delayed union and non-union in fractures of the femur is not so great as in fractures of the tibia.

4. There are more cases of delayed union and non-union in the middle third of the tibia than in the upper and lower thirds.

5. The majority of our patients received some form of calcium therapy during their fracture treatment, with little recognizable effect on the end result.

6. In the instructions to patients and students, due consideration should be given to the slowness and uncertainty of the healing of fractures of the tibia and femur, so that patients may be prepared for the long period of time possibly necessary for the healing of these fractures.

7. The use of skeletal traction and the use of internal or external skeletal fixation in no way speeds the healing time of bone, and in some instances retards it, because of distraction, infection, or the osteolytic effect of the metals used.

8. In the series of cases here presented, circumstances in some instances necessitated

the use of skeletal traction, plating, and external fixation (Haynes). In none did we feel that the results obtained by such methods were in any way superior to those of conservative treatment, when alignment could be maintained even at the expense of a loss of length of as much as three-quarters of an inch.

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ECHINOCOCCOSIS OF BONE

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HISTORY

Echinococcus disease is mentioned in the Talmud, and was known to the early Jews through their sacrificial slaughter of animals. Hippocrates, Aretaeus, Galen, Rhazes, and several physicians of the seventeenth century refer to it. Redi, in the latter period, demonstrated its animal origin, and Goeze, in 1782, accurately described the cysts and the tapeworm heads. Von Siebold (1852) infected dogs from hydatid cysts, and proved the relationship between the larva and the adult taenia. Leuckart, in 1876, described the complete life history and morphology of the parasite. Dévé, in 1901 and subsequently, through his experimental, clinical, and pathological studies of the disease and the parasite, added greatly to our knowledge. He produced the disease in the rabbit by direct inoculation. Dew, in his book (1928) and various articles, has given a very thorough account of the disease, and of its occurrence in Australia.

The North American literature begins with the report of Osler, who, in 1882, reviewed sixty-one American cases, one-third of them of foreign origin. He was unable to find the taenia echinococcus in dogs, but found it in cats, and one of his students found it in ten of 270 hogs examined. He pointed out the relation of echinococcus disease to drinking water. Sommer, in 1896, reviewed the hundred cases to that date. Lyon, in 1902, gave a third statistical study of the disease, listing 241 cases, 135 of which were his own, the origin of the patients, and the sources of the disease. Riley, in 1933, discussed the reservoirs of echinococcosis in Minnesota, and mentioned the finding of echinococcus cysts in six out of thirteen moose examined. Magath, in 1937, in a discussion of the disease in the United States and Canada, found a total of 482 reported cases, most of them in foreign-born patients who had acquired the disease before coming to this continent, and added ten cases diagnosed at the Mayo Clinic. He reported nineteen cases of United States origin, and three of Canadian, the first case being found in 1900 in each country.

BONE INVOLVEMENT

According to Gangolphe, bone involvement with echinococcosis was first mentioned by van Wy in 1786, then by van der Haar, in 1800, followed by Cullerier, in 1806, and by Chaussier in 1807. Webster, in 1819, reported from London a case of tibial involvement. Keate, in 1819, reported the disease in the frontal bone of a girl of eighteen, whom he operated upon twice, and who recovered. Other early bone cases were reported by Barckhausen (in 1819), Wickham (in 1827), Ollivier, D'Angers, Cooper, Dupuytren, Bérard (in 1851), Albanese, and Küster.

There are numerous cases of echinococcus disease of bone in the world literature, largely individual case reports. Réczey, in 1877, listed thirty-three bone cases. Gangolphe, in 1886, reviewed fifty-two cases and wrote an interesting monograph. Bauer, in 1913, summarized the 243 cases previously collected by Gangolphe, Titoff, and Reich; and Pasquali, in 1930, collected 406 additional cases. Greenway, in 1922, reported nine bone cases from Argentina; Pessano, in 1933, twenty-eight cases from that country; and Toole, in 1930, nine cases from Greece. Desplas, Boppe, and Bertrand, in 1924, tabulated forty-three pelvic bone cases; and, in the same year, Costantini reviewed fifty-three cases. Kienböch, in 1933, collected eighty-six cases and included them in an interesting monograph. Grisel and Dévé, in 1929, listed 190 spine cases. There is considerable overlapping of cases in the various summaries, and the diagnosis was not fully established in

all of the cases, but it seems safe to say that up to the present time there may be approximately 1,000 cases of echinococcosis of bone reported in the world literature.

The first case of bone involvement in North America was reported by Woods in 1899 (humerus), and it was included in the review by Lyon in 1902. Walker and Cummins, in 1917, reviewed eighty-eight cases of bone involvement in the world literature and added a second North American case (tibia). The third was reported by Hines in 1926 (vertebrae), the fourth by Stone in 1930 (pelvis), and two additional pelvic bone cases by Coley in 1932. The author, in 1932 and 1938, presented at the New York Academy of Medicine the seventh case (femur), which is more fully reported herewith. Sinberg, in 1936, reported the eighth North American case (sternum); in the Case Records of the Massachusetts General Hospital, in 1939, the ninth was reported; and Hood, Lambert, and Thomas reported the tenth (pelvis). The case reported herewith is unusual because it is one of the ten North American cases, the first with femoral involvement, and the only known instance in which the cavity was filled with bone chips after removal of the cyst.

ETIOLOGY AND DISTRIBUTION

Echinococcus disease is endemic in every continent of the world, and is especially common in Australia, New Zealand, South America, Siberia, North Africa, Asia Minor, the Balkans, and Iceland. Its prevalence bears a very close relationship to the proportion of sheep to the local population, and to the frequency with which dogs eat the viscera of sheep. The dog is the chief definitive host for the taenia, but it has also been found in some of our wild animals (wolf and jackal). The intermediary hosts are sheep, goats, hogs, cattle, and moose. The ova are shed in the faeces of the dog, which may be eaten by hogs, or may be deposited on grass eaten by sheep or cattle, or in water drunk by animals or man. The ova may be transmitted directly from the dog to the hands of man (especially little children), and thence to his mouth, particularly when he does not wash before eating. The presence of the disease in man depends upon his putting his hand to his mouth, or upon eating uncooked food, or drinking unboiled water contaminated by dog faeces, and is therefore directly related to and controllable by his sanitary habits. The disease in the dog is dependent upon his eating the infected viscera of sheep or of other animals, and can be controlled by destroying these viscera, or by keeping dogs from them,—that is, by sanitary control of slaughter houses. The Federal Meat Inspection Service, in 1924, found hogs infected in the ratio of one to 2,500, and sheep one to 60,000; but, in 1935, cattle were found to be infected in the ratio of one to 513. The Bureau of Animal Husbandry reported an incidence of 3.2 to 10,000 for cattle and 5 to 10,000 for calves in 1941. These infections probably were obtained through wild animals, as only one authentic case of dog infection has been reported in this country, largely due to the elimination of dogs from slaughter houses. The prevalent "black market", due to the War, may easily result in a reversal of this situation. The present movement of military forces and populations over the face of the earth, and poorer sanitary conditions in certain areas, will certainly result in an increase of the disease, even among our own forces.

The six-hooked echinococcus embryo measures about thirty-five micra and is covered by a chitinous envelope, resistant to exposure. The embryo loses its envelope in the upper intestine of the intermediary host. It bores through the intestinal wall to enter a vein, whence it is carried by the portal vein to the liver. The majority of the embryos remain in the liver, but some of them pass through the liver. Most of these are filtered out in the lungs. A few pass through the vessels of the lungs and lodge finally in the muscles, spleen, kidney, or bone. Thus about 75 per cent. of human lesions are found in the liver, 15 per cent. in the lungs, 2 per cent. each in the kidneys and the spleen, 4 per cent. in muscle, and 1 per cent. in bone.

The embryo provokes a cellular reaction in the tissues,—mononuclear, eosinophilic, and fibroblastic, with occasional giant cells. The embryo develops rapidly (in about

three weeks) into the larva, a cyst containing hydatid fluid and surrounded by a laminated wall, the result of intracystic pressure. The wall prevents the leakage of the specific fluid which excites the reaction in the host tissues, whereupon the reaction ceases, and the host tolerates the parasite. The wall consists of an outer laminated hyaline membrane, and an inner germinal layer, which lodges the brood capsules, filled with scolices. The fluid is a buffer, and is the source of nutrition for the scolices. It contains sodium chloride (0.6 to 0.8 per cent.) and a small amount of coagulable protein (albumin). There are usually thousands of brood capsules in a single cyst, white opaque granules just visible to the naked eye. The buds in the capsules develop into the scolices, with suckers, hooklets, and contractile tissue. There may be daughter cysts inside the mother cysts.

The dog is infected by eating the viscera of the sheep, pig, or cattle. The ingested scolex develops in the intestine of the dog into the mature cestode, a worm three to six millimeters in length, with three or four segments. One dog may harbor thousands of worms. The terminal segment houses the uterus, in which 500 to 800 ova soon develop. These mature segments are discharged in the faeces of the dog, and the life cycle of the parasite is thus continued.

DIAGNOSIS

The symptoms of echinococcus disease in man depend upon the size and location of the cyst, or, more often, upon leakage or rupture of its contents. Pressure symptoms are uncommon in the liver, lungs, kidneys, spleen, or bone. A cyst of a skeletal muscle is likely to be disturbing cosmetically rather than otherwise. Leakage from the cyst usually causes sudden and often serious symptoms. There may be an immediate anaphylactic reaction, or the disease may spread directly into neighboring tissues, especially body cavities such as the peritoneum, or in the blood and lymph streams to a more distant organ. Rupture of the cyst sometimes results in its death, especially if the rupture is external and complicated by infection. Inflammatory symptoms follow infection. Anaphylaxis is due to absorption of the specific hydatid protein in a previously sensitized patient, and may cause dyspnoea, cough, cyanosis, cardiac anxiety, fever, urticaria, pruritus, vomiting, pulmonary oedema, and even delirium.

Bone involvement occurs in about 1 per cent. of cases of echinococcus disease. The larger series of cases reported show that the pelvis is involved in about 36 per cent., the spine in 18 per cent., the sacrum in 11 per cent., the femur in 17 per cent., the tibia in 9 per cent., and the humerus in 10 per cent. Pain is the most common symptom of bone involvement, and is due to leakage or to pathological fracture. Rupture or pathological fracture may be followed by infection, with pain, swelling, redness, and tenderness; however, a mass may be noticed before the onset of pain. The mass is rounded but somewhat irregular, usually firm or hard, but sometimes semifluctuant, not tender unless infected, and attached deeply and firmly to the bone. Motion may be limited and painful, if the mass is near a joint. The inflammatory signs are present, if the cyst is infected and near the surface. The signs of fracture, bony deformity, false motion, crepitus, and disability, may be present with this complication. A vertebral lesion may cause pressure upon the spinal cord or cauda equina, with spastic or flaccid paralysis, while the spinal fluid below the lesion may have a high protein content, and there may be a partial or complete block.

LABORATORY FINDINGS

The laboratory may be of considerable help in confirming the diagnosis. Scolices, hooklets, or fragments of laminated membrane may be found in the sputum, urine, or faeces after rupture of a cyst. Three immunological tests, dependent upon antibody reaction, are usually positive if properly done, unless the cyst has remained completely sealed, or is dead. The intradermal test of Casoni is positive in about 95 per cent. of cases. This test was further developed by Dew, Kellaway, and Williams.

A more convenient test is that of Culbertson and Rose, utilizing the antigen of a related cestode, dipylidium caninum. Neither test is specific for the particular type of cestode.

The complement-fixation test (Ghedini; Weinberg; Fairley), with fresh hydatid fluid from sterile sheep cysts, is positive in about 90 per cent. of cases, depending upon whether the cyst is ruptured or infected within the previous two months. It will be negative within one year after complete eradication of the disease. The precipitin test, done with the cyst fluid of the sheep, is less dependable (Fleig and Lisbonne; Sachs-Georgi; Bryce, Kellaway, and Williams). Eosinophilia of 20 to 50 per cent. is common, depending upon leakage of the cyst contents.

Aspiration or puncture of the cyst yields the characteristic fluid, and often scolices or fragments of laminated membrane, but should not be practised because of the dangers of sensitizing the patient, of anaphylaxis if he is already sensitive, or of producing secondary cysts by implantation of the scolices which escape into the tissues. The fluid is clear and limpid, or milky, unless stained by other fluids. The scolices are white granules, just visible to the eye. Daughter cysts are milky white, opalescent, semitransparent, and hollow.

ROENTGENOGRAPHIC FEATURES

The roentgenogram may be of great value in demonstrating the presence and location of the lesion, but may not indicate its nature.[3,39] The cyst is somewhat radiopaque (of muscle density), because of its saline content, and will be seen readily in the lung fields, but it may not be distinguished in the abdomen. The bone lesions are polycystic, with fairly sharp margins, but without productive reaction or regional or subperiosteal decalcification unless infected. They must be distinguished from giant-cell tumor, the cystic type of tuberculosis of long bones, malignant tumor, osteomyelitis, and osteitis fibrosa cystica. The surrounding bone is thinned and may be even expanded or ruptured by the pressure of the lesion. Arterial occlusion results in necrosis, and small sequestra may be seen. Fracture through the involved area is not infrequent, and non-union often results.

DIFFERENTIAL DIAGNOSIS

Thus the differential diagnosis depends largely upon the possibility of echinococcus disease, upon the laboratory tests, and upon the roentgenographic appearance. A negative Mantoux test will rule out tuberculosis. Calcium, phosphorus, and phosphatase determinations may help in distinguishing osteitis fibrosa cystica, or Paget's disease. The white blood count, the erythrocyte sedimentation rate, and the temperature distinguish osteomyelitis (except cysts with secondary infection). The slow, silent course is indicative of echinococcosis rather than of malignancy.

TREATMENT

The treatment of echinococcosis of bone is unsatisfactory. No drug has been found which will safely kill the parasite, by any method of administration. Roentgenotherapy has probably never destroyed the parasite. Excision of the cyst, with or without exteriorization (marsupialization), has been the most successful treatment. Removal of the cyst carries the risks of anaphylaxis and of implantation at the time of operation. If the patient is already sensitive, leakage of fluid at the time of operation may result in an anaphylactic reaction. If he is not sensitive, he may be made so; and if there is another cyst in his body or a recurrence, the danger of anaphylactic reaction persists. Recurrence may be due to incomplete removal of the cysts, or new cysts may develop from implantation at the time of operation.

A technique has been devised by Dévé for sterilization of the cyst immediately be-

fore operation to prevent implantation or recurrence. The cyst is packed off, aspirated, and injected with 2 per cent. formalin in amount equal to the aspirated fluid. After five minutes the formalin is withdrawn and the cyst is excised. (The formalin does not usually sterilize daughter cysts, which must be removed completely to prevent recurrence.) Twenty cubic centimeters of formalin and ten cubic centimeters of acetic acid are mixed with two grams of a solution of potassium ferrocyanide in 970 cubic centimeters of distilled water, and sterilized ten minutes at 105 degrees Fahrenheit. The solution is injected after the aspiration. The method has been further modified to prevent anaphylaxis or recurrence.

Local excision of echinococcus of bone and muscle has often been unsuccessful, either because of incomplete removal, or implantation. Marsupialization has not been practised for involvement of the extremities, although it might be advisable in selected cases. Amputation of the involved extremity has removed the localized disease, when done well above the involved area, and is often the method of choice. Lesions of the spine or pelvis have occasionally been excised with good results, but more often complete excision is impossible. Possibly, in such cases, if the lesion is single, sterilization alone would be sufficient, or marsupialization with instillation of a sulfonamide. Amputation was refused in the case here presented, whereupon local excision was attempted, and bone chips were packed into the cavity.

CASE REPORT

A laborer, born in Southern Italy, emigrated to the United States in 1919. He came to the New York Orthopaedic Hospital in February, 1932. He was then forty years of age. He complained of pain in the right knee of four months' duration. Onset of pain had followed a fall in which his knee had been twisted. At that time, he was taken to an orthopaedic hospital where a roentgenogram was reported negative, and baking was given. The knee had remained swollen, stiff, and painful, requiring him to remain recumbent for two and a half months. An aspiration was done at another orthopaedic hospital three months after the onset, but no roentgenogram was made at that time. When he was admitted to the New York Orthopaedic Hospital, four months after onset, he still complained of swelling, but the

FIG. 1-A

FIG. 1-B

December 18, 1931. Roentgenograms of right knee show large polycystic lesion of lateral femoral condyle with sharp margins, and smaller cysts above intercondylar notch; erosion posterior to notch and possibly at distal lateral margin of lateral condyle; and moderate dense swelling of capsule. No productive or periosteal reaction is apparent.

FIG. 2-A

FIG. 2-B

March 18, 1932. Cysts in lateral condyle have been partially removed. There is air in the bone cavity and soft tissues about the lower femur.

pain and stiffness were less marked. He had had no previous trouble with the knee except a "sprain" eight years previously, from which he had fully recovered. He had had no cough and had not lost weight. (It is of interest that two of his small children had been recently treated for tuberculosis of the spine.)

Physical examination was negative, except that the right knee was moderately swollen, because of fluid in the joint. The tissues in the popliteal region and proximal to it were thickened. There was full extension, with flexion to 80 degrees without pain or spasm. Slight tenderness was present about each femoral condyle; the ligaments were slightly relaxed. He had a mild limp.

The Wassermann test was negative; the Mantoux, positive. The leukocyte count was 10,000, with 70 per cent. polymorphonuclear leukocytes, and 1 per cent. eosinophils. The red cell count was normal, and the urine negative. Roentgenographic examination revealed a polylocular cyst of the lower end of the femur with several perforations of the cortex. There was no marginal condensation and no expansion. Roentgenograms of the pelvis, of the spine, of the abdomen, and of the lungs were negative. Giant-cell tumor, chondrosarcoma, and tuberculosis were considered possibilities.

An exploration was performed in March 1932. An incision was made just above the lateral femoral condyle, avoiding the joint. Beneath the fascia of the vastus lateralis a cavity was encountered, containing 200 cubic centimeters of thick, light yellow, highly refractile liquid, resembling semisolid fat. This cavity communicated with the interior of the femoral condyle through a cortical perforation. It was lined with a tough, gray, rugose membrane, one-eighth of an inch thick, and had many subsidiary pockets, formed by sharp-edged crisscrossing bands.

The bony cavity was similar to that seen in the roentgenogram, the shell laterally being very thin. It was filled with ovoid, transparent, gelatinous masses about one-half an inch in diameter. There was a thin, incomplete, yellow-gray lining. Frozen section was reported to show chronic inflammation. The contents of the cavities did not resemble anything any of us had seen before, but suggested the likelihood of an echinococcus cyst.

The cavity in the popliteal region was thoroughly cleaned out, and that in the bone scooped out as well as possible without breaking down the bony partitions. Because of some uncertainty as to the diagnosis, it was considered unwise to do a more extensive procedure at this time. The wound was closed, and healed *per primam*. The postoperative course was uneventful.

Cultures gave no growth. Two guinea pigs were inoculated and eventually killed, but no disease was found. Microscopic examination of the fresh contents of the cyst revealed structureless stratified layers of amorphous material, associated with fatty-acid crystals. Sections of the bone showed a rarefying osteitis with chronic inflammation and foreign-body giant cells. The soft tissues were bounded by granulation tissue with many foreign-body giant cells in the superficial layers. Specimens were seen by Dr. Stewart of Memorial Hospital and Dr. O'Connor of Rockefeller Institute, who made a diagnosis of hydatid cyst.

Amputation was advised, as the possibility of curing the lesion seemed remote, but the patient

refused. Resection of the involved bone seemed hopeless. Accordingly, the cavities were again exposed for a more thorough curettage, and for the insertion of bone chips. The soft-tissue cavity had shrunk to one-third its former size. Both cavities were filled with old blood. No new gelatinous masses had formed, but a number of pockets remained in the bone. These were thoroughly curetted, and the cavity was carefully and completely swabbed with pure phenol, then with alcohol, and was finally curetted again to bare bone. The cavity was filled with medium-sized chips from the tibia, 250 cubic centimeters of bone chips being required. A long leg cast was applied, as the remaining bone was quite thin. The wound healed *per primam*.

FIG. 3-A

FIG. 3-B

May 4, 1932. Bone cavities have been fully excised and snugly packed with numerous small chips. The air has disappeared.

FIG. 4-A

FIG. 4-B

July 28, 1933. Chips have coalesced and cavities have been obliterated, except for several small areas near lateral and distal margins of lateral condyle.

Seven weeks after the operation there was no tenderness, redness, swelling, or joint fluid. The range of flexion was 180 to 115 degrees. There was no induration about the wound, nor was there any popliteal mass. Weight-bearing was begun at this time. Five weeks later, the flexion had increased to 60 degrees. Seven months after the operation, the patient had no pain or fatigue and was active without handicap. He could walk several miles, and had no limp or limitation of motion. There was moderate joint fluid and periarticular thickening, and slight warmth. There was no pain, tenderness, or spasm. Flexion was 180 to 45 degrees. No recurrence of the disease could be seen by roentgenogram. Gradually the chips became more confluent.

One and one-half years after the operation, the swelling of the knee increased, and aspiration yielded fifteen cubic centimeters of glairy, sparkling, yellow fluid. The swelling and thickening persisted, and there was some disability. It appeared definite that the knee joint was involved.

FIG. 5-A

FIG. 5-B

September 17, 1934. Further coalescence of chips is evident.

FIG. 6-A

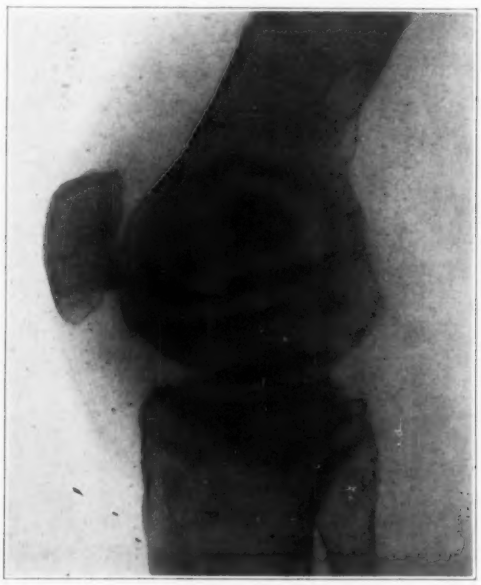

FIG. 6-B

September 17, 1935. Roentgenograms taken before synovectomy show thin joint space and marked, dense swelling of capsule. Lesion in femur is unchanged.

In September 1934, two and a half years after the first operation, the knee joint was explored. One hundred cubic centimeters of cloudy, yellow fluid, with fibrin flakes and masses, were obtained. The synovial membrane was pale red. Villous processes were free in the joint. Extending from the superomedial corner of the suprapatellar pouch, into the middle third of the thigh, was a prolongation of the cavity, with dirty gray walls. The femoral articular cartilage and the medial meniscus were degenerated, but were not involved by the disease. A complete anterior synovectomy was performed, including the menisci. The wound healed *per primam*, and the patient began walking in ten days, with 30 degrees of motion.

Microscopic examination showed a thick synovial membrane, with numerous villi, and a dense fibrous-tissue base with many foci of lymphocytic infiltration. There were many cystlike structures of various sizes. These exhibited walls made up of an outer layer of fibrous connective tissue, an intermediate layer of epithelioid cells and giant cells, and a partially detached inner layer of laminated cellular acidophilic membrane. Some of the cavities contained firmly granular material. Numerous less fully developed tubercle-like structures appeared to be early stages in the evolution of the cyst.

For one year following synovectomy the patient had no pain, little disability, and good motion, but he had moderate relaxation at the knee. Then the swelling increased, the knee became weaker, and his limp became troublesome. Motion was limited to 75 degrees. There was moderate fluid and thickening; the knee was warm, and the veins were swollen. Roentgenograms revealed activity in the bone lesion, with effusion in the knee. Amputation was advised, but was refused. In January 1938, three years and four months after synovectomy, the knee was still worse. Roentgenograms (Figs. 7-A and 7-B) showed increasing involvement, and amputation was again advised. A few days later, six years after the original operation, he sustained a pathological fracture through the cyst in the lower femur and developed a severe anaphylactic reaction. He was taken to a hospital in Brooklyn where amputation was performed. Request for half of the specimen was not granted.

The patient was last seen in October 1942. The amputation stump was well healed, and there was no evidence of echinococcus disease in the stump, or elsewhere in his body. He died of cardiovascular disease in July 1943.

SUMMARY AND CONCLUSIONS

The development of our knowledge of echinococcus disease has been outlined, and its etiology and distribution have been described. The disease is rare in this country, but not uncommon in other areas, and its increase may be expected because of conditions growing out of the War. Its diagnosis, especially in bone, is not difficult, if its possibility is realized, and if proper laboratory tests and roentgenograms are made. Treatment has been unsatisfactory to date. Marsupialization or sterilization of the cyst sometimes may be

FIG. 7-A

FIG. 7-B

January 15, 1938. Moderate destruction of both femoral condyles has occurred, especially distally, with erosion and collapse of the cortex distally and posteriorly. Soft-tissue swelling is very marked and dense.

successful. Roentgen radiation has failed. Removal of the entire diseased area has removed the disease, but is mutilating. Insertion of bone chips will not be successful, unless the disease has been eradicated.

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ANALYSIS OF ONE HUNDRED CONSECUTIVE ARTHROTOMIES FOR TRAUMATIC INTERNAL DERANGEMENT OF THE KNEE JOINT

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INTRODUCTION

This analysis is based on selected clinical material in the files of a mutual assurance company, existing primarily for the benefit of mine workers. So much in advance of existing legislation and state hospitalization has been the medicolegal and industrial-surgical practice of this company, that many of the recent advances in medicine in South Africa can now be traced to its progressive methods.

MATERIAL

In the especially designed industrial hospital in which this study was undertaken, the major traumatic surgery for 40,000 European male employees is carried out by a staff of full-time and part-time salaried specialists. Clinical records are dictated at the time of examination, operation, and follow-up examinations, and are then typed, filed, and cross-indexed.

Of some 8,000 injuries reported during a year, a considerable number are knee injuries,—such as penetrating wounds of the joint, contusions, fractures, and ligamentous injuries. For the purposes of this investigation, 100 consecutive arthrotomies for traumatic internal derangement performed during 1939–1940 were chosen. This number represents only about one-third of the arthrotomies performed during that time, but the series has the virtue of having been dealt with according to a pre-arranged routine of examination, operation, and after-treatment by one surgeon (G. T. du T.). Final assessments of disability were made by the surgeon, affirmed or altered by the senior consulting surgeon, and checked by the administrative medical officer and his staff.

Most of the employees worked underground at deep rock mining, which involved travel by cage down to 6,000 feet, crawling on hands and knees in low stopes twenty-eight inches high, and sliding along on bellies or buttocks over wet, irregular, slippery rock faces which slope up to 40 degrees. They wore heavy leather boots with metal-studded soles; any other footwear was forbidden by regulations. Hazardous barring down of unsafe rock, dodging of falling rock, moving scrapers, cocopans, slipping on wet metal rails or wooden supporting sprags,—all constituted special dangers and required normally functioning knees.

An injured miner who feels himself unable to carry on does not hesitate to report himself sick, since adequate medical attention, plus 60 per cent. of his wages, as well as subsequent surgical attention by a specialist, is provided. Following operation, an *ex gratia* payment in cases not entitled to permanent disability benefit compensates for most of the loss of wages.

Arthrotomy was not performed until a definite diagnosis of internal derangement had been made. Doubtful cases were treated conservatively by physiotherapy, pending later re-assessment. Very few of these men were allowed back underground for a trial period, while the diagnosis was uncertain.

ROUTINE OF EXAMINATION

For the purpose of examination, the patient was stripped and dressed in a pair of trunks. The following points were tested by the surgeon and recorded by a typist. This

was found to be the only accurate method of keeping records of the examination. The findings of the normal knee were used as a control wherever possible.

Passive extension was tested by forcing the knee into full extension, and noting the site of the pain. Loss of full extension was never found to be painless.

Passive flexion was tested by pushing the patient's heel to his buttock. Limitation of this movement was rarely significant, since even slight effusion produces such limitation.

Effusion was tested by fluctuation and patellar tap.

Patellofemoral crepitation was determined by moving the patella up and down, and sideways on its femoral groove.

Joint crepitation was discovered by moving the joint in the normal manner without weight-bearing, and by palpating the joint during the process. Very frequently, the patellofemoral crepitus would be present with a perfectly smooth main joint.

The tibial collateral ligament was tested in full extension by passive straining of the fully extended knee joint, and degrees of laxity were assessed with a +, indicating the minimum undue laxity, and +++ indicating a complete rupture.

The fibular collateral ligament was examined in the same manner.

The anterior and posterior cruciate ligaments were tested with the patient lying on his back, the knees flexed to a right angle, and the surgeon sitting on both feet of the patient and rocking the head of the tibia backward and forward. Undue *forward* sliding of the tibia was interpreted as anterior cruciate laxity, and undue *backward* displacement of the tibia as posterior cruciate laxity. It was kept in mind that during these tests the musculature had to be completely relaxed. This was usually effected by drawing the patient's attention to something else. The absolute absence of laxity was called normal, but there can be no doubt that knees, capable of perfect physiological function, may nevertheless have slight anteroposterior mobility according to this test. Such knees were classified under +. laxity. At operation, it was discovered on several occasions that complete rupture of the anterior cruciate ligament had only been given ++, instead of +++, at preoperative examination by several observers. Attention is drawn to the fact that when the collateral and posterior cruciate ligaments are intact, complete rupture of the anterior cruciate may be masked to a certain extent.

Internal Rotation of the Tibia: This manoeuvre was first demonstrated to the authors by Fouché, who has taught it to several generations of surgeons. It has been a source of interest to visiting military orthopaedic surgeons from abroad, and we have come to regard it as an invaluable contribution to the diagnosis of internal derangement of the knee. The test is carried out on the right knee, with the patient flat on his back on a couch, with his hip and knee fully flexed. The left fingers of the examining surgeon are held on the anteromedial joint line, the right hand firmly grasping the patient's right foot, which is used as a lever in internally rotating the tibia on the femur. The motion is carried through as a complete circumduction movement, starting with the knee fully flexed, and ending with it slightly flexed. The menisci move with the tibia, and the posterior end of the medial meniscus is nipped between the femoral and tibial condyles, the tendency being for the femoral condyle to force the meniscus toward the center of the joint. It may move a small distance, and then slip back, producing an audible and palpable thud. With practice, one is able to recognize this normal thud, and to distinguish it from other sounds. The sound which a torn meniscus may produce varies with the type of tear. From a grossly torn and frayed meniscus may be elicited a crunch or squelch; from a narrow bucket-handle strip of cartilage, a high-pitched click; or from multiple splits in the posterior part of the meniscus, a succession of clicks. A broad rim of meniscus which is partly loose may cause only exaggeration of the normal thud; while the reduction or the dislocation of a wide bucket-handle portion causes a loud crack and a jolt. This test should be distinguished from the McMurray sign, in which the knee is held in full flexion, with the tibia in external rotation, and then gradually extended until a click occurs as the medial

femoral condyle crosses the lesion in the meniscus. The manoeuvre we describe is just the reverse, in that it does not re-duplicate the strain which produces the original lesion, as the McMurray test is supposed to do.

External Rotation of the Tibia: The manoeuvre for internal rotation of the tibia is reversed for the detection of lesions of the posterior half of the lateral meniscus. For this purpose it has been found to be of considerable value.

Manipulation of the Knee in 20 Degrees of Flexion: This manoeuvre is carried out with the patient's knee relaxed. The examiner puts one hand on either side of the joint, and circumducts the knee in a small circle, meanwhile holding his thumbs on the joint line on either side. Although the results of the previously described manoeuvre may have been negative, by this method, it is often possible to elicit thuds or clicks, due to tears situated farther forward, near the anterior attachments of the menisci.

Manipulation under Anaesthesia: This examination was rarely resorted to, and usually gave very little help. When the diagnosis remains in doubt after adequate clinical examination, one feels safe in assuming that the internal derangement, if any, is not sufficiently severe to warrant arthrotomy. The surgeon can learn to distinguish between the various sounds in the relaxed knee of a cooperative patient. The pain associated with the normal sound is usually of value in diagnosis, and anaesthesia robs one of this evidence. (Incidentally, a completely negative manipulation does not necessarily imply a normal meniscus, nor exclude the possibility of a completely displaced bucket-handle portion lying in the intercondylar notch.) In a few cases where manipulation was not possible because of the patients' remonstrances, and where the evidence presented by the other signs and the history was inconclusive, subsequent events proved that operation was unwise on any grounds except an absolute clinical diagnosis. When the diagnosis is uncertain, it is better to defer the decision. The pain in a fresh, severe injury may be genuine; but, in injured workmen, a certain amount of scrimshanking may be suspected.

The site of pain in the knee was determined by asking the patient to point it out, and then testing individually the four attachments of the collateral ligaments, and the four quadrants of the joint line by direct pressure. Tenderness in the anteromedial joint angle is always a very significant finding, and will be discussed later in the paper.

Crushing Sign: In testing for laxity of the collateral ligaments, it was soon discovered that pain was often elicited over the torn medial meniscus by adduction of the tibia on the femur as a result of crushing the torn and painful tissue. Abduction in turn elicited pain when the lateral meniscus was torn.

Mensuration: The routine measurements of the circumferences of the limbs were taken at points measured from the anterior superior spine, usually at the mid-thigh, suprapatellar, joint-line, and mid-calf levels, with the legs relaxed on the couch. With but one examiner, individual variations were excluded.

Reflexes: Knee jerks, ankle jerks, and plantar response were tested as a matter of routine.

The mouth and throat were always investigated for focal sepsis.

OPERATIVE TECHNIQUE

Preoperative skin preparation was carried out for seventy-two hours, as a gesture to the orthodoxy of surgical practice. The writers believe that joint surgery is safe through skin, thoroughly cleansed with soap and water twelve hours before operation, completely shaved, and prepared with any one of a number of skin antiseptics. In this series, tincture of merthiolate was used for the final preparation, 70 per cent. alcohol being used for the previous five preparations. Since the work had a medicolegal aspect, it was felt that, in the event of septic complications of knee operations, the surgeon might not have the support of the "old school", should the preoperative preparation depart radically from orthodox practice.

TABLE I

FINDINGS REVEALED BY MANIPULATIVE EXAMINATION IN SEVENTY-NINE CASES

Lesion	Sound Diagnosed As Pathological	Sound Doubtful	Soundless Manipulation
Bucket-handle tear	18	6	23
Posterior horn, marginal	1	0	1
Posterior horn, tag	6	1	1
Anterior horn, marginal	2	0	0
Anterior horn, tag	1	0	0
Multiple lesions	5	4	4
No tear	2 *	4 *	0
Total	35 (44 per cent.)	15 (19 per cent.)	29 (37 per cent.)

* In these cases the findings on manipulation were misleading. See Table VII.

In the ward, a locked knee joint was invariably kept on a pillow in order to prevent ligamentous strain.

General anaesthesia, a bloodless field, and a non-touch technique were employed throughout the series. A longitudinal parapatellar incision across the joint line was employed for medial meniscectomy; and, for removal of the lateral meniscus, the oblique downward and forward incision, through the fascia lata, was found to give adequate approach, to interfere least with the extensor aponeurotic structure, and to be easily sutured, the edges falling together when the knee was extended.

Subcutaneous bleeding points were ligated. The infrapatellar branch of the saphenous nerve was invariably divided by medial incisions, and the anatomically constant extrasynovial artery (branch of the highest genicular artery) was sutured before the joint was opened.

The incision into the synovial membrane was made from the medial border of the patella to the tibial joint line, thus allowing adequate inspection of the joint. This inspection was carried out in a routine manner by first noting the character of the fluid, then pulling on each meniscus with a blunt hook to test for mobility. By retraction the patellar articular surface was inspected directly for evidence of traumatic lesions of the cartilage. By retracting the infrapatellar fat pad, the opposite side of the joint was examined. In four cases in this series, it was impossible to see the lateral meniscus from the medial side because of an almost complete synovial septum in the middle of the joint.

In bucket-handle lesions of the meniscus, the peripheral margins were invariably dissected out also, in order to avoid missing secondary longitudinal splits in the posterior third. After the peripheral synovial attachment had been freed at its line of reflection with a straight tenotomy knife, the marginal portion could usually be displaced into the intercondylar notch.

When osteochondritis dissecans was discovered, a few drill holes were made into the bare-bone floor of the lesion. The wound was closed in layers, and a very large wool dressing was applied in moderate tension. The dressing was designed for comfort, rather than for purposes of minimizing postoperative extravasation.

Postoperative Routine

The foot of the bed was raised on eight-inch blocks. On the second day, active foot and ankle movements were started, and on the third day, active quadriceps contractions were begun. Straight-leg raising, ten times per hour, was initiated on the fourth day, and active flexion to the extent permitted by the dressing was allowed on the seventh day. On the twelfth day, the stitches were removed, and the patient was seated in a wheel chair. Thus the knee was unconsciously flexed to 90 degrees. The quadriceps drill was maintained. The patient was usually able to lift his knee 200 times at a sitting on the four-

teenth day; and beginning at this time, he was allowed to attempt walking with the aid of a cane. On the sixteenth or seventeenth postoperative day, the patient was formally discharged, but continued in daily attendance in the out-patient department, travelling by bus or tram to the hospital. From the fourth week, the patient was instructed to swim, ride a bicycle, do antigravity weight-and-pulley exercises, or stationary row-boat exercises, and to walk several miles daily. Work was usually resumed at the end of the sixth or the seventh week.

The follow-up of these patients depended upon the fact that each man was told that, if the knee gave any trouble whatsoever, he was to report to the medical officer of his own mine, who would then refer him to the head office for re-examination, further treatment, or final assessment of disability. It is now four years since the last case in this series was treated.

OPERATIVE FINDINGS

Of the lesions found at operation, eighty-two were tears of the medial meniscus, nine were tears of the lateral meniscus, and three patients showed medial and lateral tears in the same knee. Two knees had discoid but untorn menisci, and there were four cases in which no lesion of the meniscus was discovered.

Of ninety-seven torn menisci, forty-nine were bucket-handle. This high percentage (50.5 per cent.) is accounted for by the postponement of operation until diagnosis of meniscal lesion was quite certain.

On the basis of systematic examination of intra-articular structures at operation, and of prompt recording of findings, we are able to state that multiple lesions were common, and often included traumatic degenerative arthritis.

There were two patients with osteochondritis dissecans and many with traumatic lesions of the cartilage of the medial facet of the patella,—the so-called "hot spot", associated with the name of Fouché, our pioneer orthopaedic surgeon.

Diagnostic Sounds

Manipulative examination revealed the findings in Table I.

Pain

Pain at the joint line was recorded in ninety-nine knees,—198 medial and lateral sides. Ninety-six sides had torn menisci, and 102 had healthy menisci, as judged by operative and follow-up findings. Of the ninety-six torn menisci, ninety-three had pain over the same side, and three patients did not suffer pain.

In six cases erroneous diagnoses were made. This led to unnecessary arthrotomy in two cases (one had pain at the medial joint line and a strained tibial collateral ligament, but no cartilage tear; the other had medial joint-line tenderness, a contused infrapatellar fat pad, and no cartilage tear). An unnecessary extra incision was made in two cases (one had bilateral pain with a lateral cartilage lesion; the other had a tear of the lateral meniscus, strain of the tibial collateral ligament, and medial pain). Two knees had discoid but untorn menisci.

In four cases of bilateral pain, a unilateral lesion was diagnosed correctly from positive manipulative findings, and preponderance of tenderness on the side of the lesion. In two cases, bilateral meniscal tears occurred with unilateral pain.

In two cases, diagnoses of meniscal tears were made in spite of the absence of pain at the joint line. *Both proved erroneous!*

Since tenderness due to ligamentous strain is typically elicited at the upper or lower bony attachments, pain on pressure at the joint line, just in front of or behind either collateral ligament, must be carefully sought for. When positive, this sign is valuable; when negative, arthrotomy should be postponed, unless the other diagnostic findings are conclusive.

TABLE II
INCIDENCE OF LOCKING

Lesion	History of Locking *Number of Cases*	No History of Locking *Number of Cases*
Bucket-handle tear	55	8
Anterior, marginal tear	2	0
Anterior horn, tag	1	0
Posterior, marginal tear	1	4
Posterior horn, tag	1	7
Multiple tears and unusual types	8	7
No tear	1 (Case 99)	5
Total	69	31

Contralateral pain is questioned as a diagnostic finding. Of nine patients with tears of the lateral meniscus, six had lateral joint-line pain, two had bilateral pain, and one had medial pain. This last case and one case with bilateral pain had concomitant strain of the medial collateral ligament.

Locking

Locking for the purpose of this investigation was defined as a mechanical block to free extension of the joint. Unlocking was never deliberately attempted; although, in the course of manipulative examination, four of the series unlocked with a thud which was recognized as pathological, and, therefore, was diagnostically significant. Out of a total of fifteen cases with bucket-handle tears and a loss of extension of 15 degrees, eleven did not unlock, and they were soundless on manipulation. A marginal posterior tear caused locking, which could be unlocked with a click on kicking the leg straight. Similar momentary locking was caused in another case by a small tag of meniscus. In a third case, a torn stump of anterior cruciate ligament was responsible for locking. Case 87 is an example of this condition.

CASE 87. A man reported two days after injury that "while travelling in a skip, the hoist tripped out" and he had jarred his hip and knee slightly. He stated that his knee gave him no trouble. However, seven months later, in changing his position while squatting, the knee locked suddenly and painlessly for the first time. Operation revealed a bucket-handle medial meniscus.

From the medicolegal point of view, it should be accepted that a very minor trauma may produce a torn meniscus. Although clinical manifestations following trauma may be delayed for months, lack of pain does not exclude the possibility of a tear.

Several patients were unable to extend the knee immediately after injury, but straightening gradually took place; therefore, these cases were counted as without locking. In some patients, definite cartilage lesions capable of locking were found; in others, a contused infrapatellar fat pad; and, in some, pain alone appears to have been adequate explanation for inability to extend the knee. Table II shows in detail the relation of locking to the various types of lesions found.

In the positive cases, the cause of locking, as far as could be determined, was as follows: Of sixty-nine cases, the meniscal lesion was responsible in fifty-nine; in eight cases, either a meniscal lesion or a nipped infrapatellar fringe was the causative factor; in one case a pedunculated fatty mass attached to the middle of the anterior cruciate ligament was the cause (there was also a meniscal lesion which could not have caused locking); in another case a discoid meniscus may have been at fault, but it is probable that the patient (Case 99) gave a misleading story.

CASE 99. This man reported the fourth day after injury. On that day he told the examiner that he had rolled fifteen feet down a slope, and bumped the inner side of his knee against a sprag, but that he was not quite sure as to what had happened to his knee. On the ninth day, he reported that when he

straightened his knee after sitting on his haunches, he felt a crunching thud momentarily. On the twenty-third day, he said that, after rising from his haunches, there was a click in the knee, and subsequently he was unable to straighten his knee. Examination revealed no limitation of extension. At operation, a discoid lateral meniscus was evident, without a tear.

There was also difficulty in analyzing the sign of limitation of passive extension, and there were a number of difficult borderline cases. (See Tables III and IV.)

TABLE III

PATIENTS WITH MENISCAL LESIONS SHOWING LIMITATION OF PASSIVE EXTENSION

Degree of limitation of extension	0	5	10	15	20	25	40	45	50	90
Number of Cases (Total 93)	27	28	21	6	4	3	1	1	1	1

TABLE IV

PATIENTS WITH LIMITATION OF EXTENSION NOT DUE TO MENISCAL LESION

Limitation of Extension (*Degrees*)	Nipped Synovial Fringes	Pedunculated Stump of Anterior Cruciate	Absence of Mechanical Obstruction
5	2	1	2
10	0	0	3

In eight out of sixty-six cases with limitation of extension, the meniscus was not the cause. These cases are analyzed in Table IV.

All of the patients included in Table IV had pain at examination when extension was forced, and in five cases, the forced extension was clearly the sole cause. We are not aware that a portion of the anterior cruciate ligament has been previously considered as a cause of internal derangement. Since then we have noted this finding in two additional cases.

A longitudinal meniscal tear with a bucket-handle portion in the intercondylar notch may cause limitation of extension of varying degree, depending upon how far forward the tear extends. In one case locking occurred with loss of extension of only 5 degrees. If the tear extends so far forward that the medial condyle of the femur moves throughout its course within the gap in the meniscus, there is no loss of extension. Ligamentous laxity may mask obstruction.

In each of seventeen cases with 15 degrees or more of limitation, the meniscus was torn in such a way that it might have caused the block. Fifteen of these lesions were bucket-handle tears, whereas, had this group of seventeen been representative of the whole series, there would have been only nine cases of bucket-handle tear.

We conclude that a limitation of extension of 5 degrees is not significant; 10 degrees is suggestive, but limitation of 15 degrees is almost certainly due to a mechanical block, caused by a meniscal lesion or a loose body.

TABLE V

ANALYSIS OF PATIENTS WITH WASTING OF THE QUADRICEPS

Period elapsed since injury	1–10 Days	11–100 Days	Over 100 Days	Total
Low thigh circumference less than uninjured thigh, therefore, wasting present.	29 cases (37 per cent.)	4 cases (5 per cent.)	8 cases (10 per cent.)	41 cases (52 per cent.)
Thigh circumference same as uninjured thigh, therefore, wasting not present.	18 cases (23 per cent.)	15 cases (19 per cent.)	4 cases (5 per cent.)	37 cases (47 per cent.)

TABLE VI

CREPITATION FOUND IN CONJUNCTION WITH OSTEOCHONDRITIS OF THE PATELLA

	"Hot Spot" 21 Cases	No "Hot Spot" 79 Cases
Patellofemoral crepitus present	72 per cent.	20 per cent.
Patellofemoral crepitus absent	28 per cent.	80 per cent.

Wasting

In clinical teaching, wasting has long been considered as a typical occurrence accompanying meniscal lesions. This wasting usually occurs very rapidly, even within a few days. It has been held that the absence of wasting excludes the diagnosis of serious intra-articular lesions.

The seventy-eight cases with meniscal tears, and on which data on circumferential measurements of thigh and calf were available, were divided into groups according to the period which had elapsed since injury (Table V). Three-eighths of an inch or more of reduction in circumference was arbitrarily labeled wasting.

In two cases which showed wasting, it was proved at arthrotomy that no lesion existed, other than a strained medial collateral ligament, and a nipped synovial fringe, respectively. It is common knowledge that a wide variety of lesions of the knee, minor and major, may lead to wasting.

We conclude that, while the presence of wasting may be of contributory diagnostic value, *the absence of wasting does not necessarily preclude meniscal damage*, irrespective of the delay between examination and injury. From the medicolegal standpoint, this is a significant observation. How often has the patient's word been doubted, because of absence of wasting in the presence of gross meniscal damage!

Patellofemoral Crepitus and Degenerative Arthritis

In 21 per cent. of this series, arthrotomy revealed an area of degeneration of the articular cartilage on the medial facet of the patella. The early appearance is that of softening and swelling of the cartilage, which looks sodden, and pits on pressure with a blunt point. Later the apex of the swelling separates, leaving a crater down to bare bone.

In our opinion, this is the site of the first appearance of degeneration of the articular cartilage in the knee joint. It is commonly seen in arthrotomies for lesions of the medial meniscus, and often occurs in patients who are not miners.

Clinically, patellofemoral crepitation may be velvety and synovial, or grating and associated with gross articular damage.

Analyzed in relation to traumatic lesions of the patella revealed at operation, our findings appear in Table VI. It will be seen that synovial crepitation frequently existed

TABLE VII

ANALYSIS OF THIRTEEN POSTERIOR MENISCAL TEARS

Type of Lesion	History of Locking	Limitation of Extension	Positive Manipulative Findings
Tear of posterior horn	17 per cent.	0 at 15 degrees 23 per cent. at 10 degrees	70 per cent.
All other lesions in the series	77 per cent.	22 per cent. at 15 degrees 25 per cent. at 10 degrees	38 per cent.

TABLE VIII

CASES IN WHICH ERRONEOUS DIAGNOSES WERE MADE

Case History	Case 22	Case 53	Case 61	Case 99	Case 60	Case 84	Case 8	Case 83
Pathology found	None	None	Discoid medial meniscus	Discoid lateral meniscus adherent to tibia	Osteo-chondritis	Large nipped synovial fold	Bucket-handle tear of lateral meniscus	Bucket-handle tear of lateral meniscus
Preoperative diagnosis	Internal derangement. Medial incision advised	Tear of medial meniscus	Torn medial meniscus	Torn displaced lateral meniscus	Torn medial meniscus	Torn displaced lateral meniscus	Bucket-handle tear of medial meniscus	Torn medial meniscus
History of locking	No	No	No	Yes	No	No	Yes	Yes
Significant limitation of extension	None	None	None	None	None	None	None	None
Pain at the joint line	No	Yes	Yes	Yes twice No once	No	Yes	Bilateral	Medial only
Diagnostic sounds at manipulation	No twice Yes once	No twice Yes once	Yes	Yes 4 times ? once	No once Yes once	Yes	No	Yes crunch medially
Wasting	Yes	No	No	No	No	Yes	Yes	Yes
Crushing sign	Yes	No	No	No	No	No	No	No
Effusion	None present, later after a walk	Slight	Present	None	Slight	None	?	Present
Doubt in the diagnosis	Yes	Yes	No	Yes	Yes	No	No	No
Tibial collateral strain	Yes	Yes	No	No	Yes	No	No	Yes

in conjunction with these changes in the cartilage, although they were sometimes found without clinical signs.

Crushing Sign

In seventeen positive cases—that is, with pain present over the meniscus which is compressed by adduction or abduction of the tibia—there was one case without a meniscal lesion. It is not, therefore, as pathognomonic a sign as our clinical impression had led us to believe.

Posterior-Horn Lesions

In this group, accurate preoperative diagnosis is the basis upon which meniscectomy is performed. When the knee is opened anteriorly, the meniscus looks and feels firm on being pulled upon; nothing abnormal is noted. Nevertheless, one should proceed with the meniscectomy, for, after detaching the anterior end, and while proceeding with the marginal separation, a long tag or a posterior tear will suddenly be demonstrated far back. Thus the meniscectomy is justified.

In our experience, it has been a mistake to close a joint without first removing the meniscus, once a lesion has been definitely diagnosed. The only exception to this practice is when gross ligamentous laxity allows full inspection of the suspected meniscus.

In Table VII will be found an analysis of thirteen posterior meniscal tears. This shows that locking is infrequent; and in this group locking is often followed by unlocking. Positive manipulative findings are common and valuable in determining the site and the side of the lesion.

Marginal Lesions

Marginal lesions are alleged to heal often with conservative treatment. In this series it was accepted that conservative treatment prevented the patient from working, because there was no "light work". In only seven cases out of ninety-four, were there tears through vascular, peripheral parts of the meniscus. Therefore, operation was justified in eighty-seven by the lesion, and in the other seven by the fact that time was undoubtedly saved, and recurrence was avoided. In three of the seven cases there were subsynovial tears,—that is, although there was no open split between the meniscus and the capsule, a synovial fornix dipped down between them, and the meniscus, when pulled upon, slipped well into the joint. In two of the three cases, hemarthrosis verified the intra-articular trauma.

Investigation of seven cases with marginal tears revealed no pathognomonic sign. Easy locking and unlocking, manipulative findings, and joint-line tenderness were all too variable to be of specific diagnostic value. Three of these patients tried working for one, one and a half, and five months, respectively, but in all cases arthrotomy was finally necessary. We believe that, once a meniscal lesion has been diagnosed, even one trial of conservative treatment is unjustifiable.

Erroneous Diagnoses

In Table VIII are grouped eight cases which were erroneously diagnosed, some of which have been mentioned separately under previous headings.

In the six cases where a meniscus was not torn, the decision to operate was usually based on (1) the failure of a trial of use of the knee, and (2) the manipulative findings. The latter, in four cases, though finally accepted as positive, were equivocal in that they varied at different examinations. It should be emphasized that in some cases, despite an incorrect diagnosis, arthrotomy was justified. In this group of erroneous diagnoses, two noteworthy features were the doubt which accompanied the diagnosis, and the frequent presence of strain of the tibial collateral ligament.

RESULTS OF ARTHROTOMY

For purposes of comparison, a number of cases were chosen in which, apart from the meniscal tear, there were no pathological changes detectable, clinically or at operation,

TABLE IX
RESULTS OF ARTHROTOMY

Complications	No. of Cases	Patients Receiving Compensation		Average Compensation Per Capita for Permanent Disability	Average Number of Days from Work after Operation
		No.	*Per cent.*		
"Uncomplicated" group	14	0	0	0 per cent.	49
Postoperative sepsis; septic arthritis severe	2	2	100	15 per cent.	127
Postoperative sepsis; septic arthritis mild	3	2	67	3.3 per cent.	99
Degenerative arthritis; well marked	3	3	100	11 per cent.	58
Laxity of ligament; well marked	5	5	100	4 per cent.	66
Well-marked post-operative effusion	6	2	33	1.1 per cent.	50
Nipped fringes at operation	8	2	25	1 per cent.	53
Degenerative arthritis; slight	13	4	27	0.8 per cent.	50
Concomitant medial ligament strain	6	2	33	0.8 per cent.	53
Laxity of ligament; slight	13	0	0	0 per cent.	47

where the operation involved only one standard incision, and where there were no post-operative complications.

The results in this group of fourteen patients, as compared with those with various complicating factors, appear in Table IX.

CASES WITH COMPLICATIONS

The three most serious cases in this series of cases with complications are described in detail, as it is felt that they are of unusual interest.

CASE 8. An underground miner, thirty-five years old, worked for five months with the lateral meniscus completely "bucket-handled" into the notch. Eighteen days prior to the operation the patient had had a complete dental clearance for pyorrhoea. Two incisions were used in the operation. On the third postoperative day, the patient's temperature was 100 degrees; his pulse was 84. There was unusual postoperative pain, and the superficial subinguinal glands were tender. On the sixth day, the temperature was 101 degrees; the pulse was 96. The patient was suffering from throbbing pain. The dressings were removed, and cellulitis around both incisions was observed. All skin sutures were removed, and thick yellow pus was evacuated from both wounds. There was no effusion, and the patient had free joint motion. Laboratory examination showed the presence of pus cells with staphylococcus albus. The granulating area in the mouth was swabbed, and the laboratory reported pus cells, non-hemolytic streptococcus, pneumococcus, staphylococcus aureus, and diphtheroids. The wounds became granulated and healed. The patient was discharged from the hospital on the seventy-ninth postoperative day, and he resumed work 126 days after the operation. He had loss of extension of 5 degrees, loss of flexion of 10 degrees, and quadriceps wasting of one and a half inches. There was some periarticular thickening, and slightly increased laxity of the anterior cruciate. A permanent total disability assessment of 7.5 per cent. was made. On examination four years later, the patient's knee was normal except for adherent scars. He had full range of motion, powerful quadriceps, no ligamentous laxity, and absence of joint crepitation.

CASE 99. A learner, twenty-seven years old, following a fifteen-foot fall, was found to have an indefinite derangement of the right lateral meniscus with associated hyperpiesis and albuminuria from long-standing renal disease. A congenitally malformed lateral meniscus, without evidence of trauma, was removed. Operation was followed by oedema around the wound, delay in healing, and subcutaneous collection of fluid communicating with effusion in the joint. Serous discharge broke through the incision, which on culture proved to contain staphylococcus aureus. A few days later thick pus drained directly

from a sinus in the knee. Later swabs were sterile, although the temperature was 102 degrees and the pulse was 120. Moderate pain on passive movement confirmed the diagnosis of infectious arthritis. The sinus healed by granulation, and the patient resumed work 103 days after the operation. At that time, there was no effusion. He had one inch of wasting of the quadriceps, slight periarticular thickening, and range of motion from 180 degrees to 60 degrees. There was a permanent total disability assessment of 15 per cent.

CASE 32. An underground-shift boss, thirty-two years old, had a bucket-handle medial meniscus removed, following several weeks of treatment for a slightly pustular skin condition. Eight days after operation, the patient's urine was very thick, and it contained pus cells, phosphates, and abundant staphylococcus albus. The temperature was 99 degrees; the pulse was 96. The patient had a slight chill. On the tenth day, the dressing was removed for the first time, and, as the stitches were taken out, a considerable quantity of pus welled out of the center of the wound. This contained hemolytic staphylococcus aureus on culture. Until then the patient had not complained of pain in the knee, nor was there any effusion. On the twelfth day, there was extensive effusion and excruciating pain on the slightest motion. Diagnosis was made of acute suppurative arthritis. The patient resumed work 150 days after operation, the knee having a range of motion from 175 degrees to 85 degrees. There was no increase in preoperative laxity of the ligaments, no effusion, and only slight patellofemoral crepitation. There was some limitation of internal and external rotation of the flexed tibia, and one inch of wasting of the thigh. A permanent total disability assessment of 15 per cent. was granted. (Our usual assessment for bony ankylosis in the optimum position is 30 per cent.)

Cases of degenerative arthritis were due sometimes, but by no means always, to the wear and tear of an aging joint. In a few cases, the repeated traumatic effect of a long-neglected torn cartilage was clear. In others, there was obvious evidence of trauma to the articular surfaces, due to the injury itself, as in the following case.

CASE 83. The man reported: "I stepped back, tramped on a block, and my knee twisted. I fell and had a severe pain in my knee. Then as I bent my knee, I heard a grating noise." There was no previous injury. At operation eight days later, the articular surfaces of both the femoral condyles and of the lateral tibial condyle were found to be damaged. In places they were broken into innumerable small fragments, some of which were loose. The lateral meniscus lay in the notch, torn in a bucket-handle manner. This case was later assessed at 10 per cent. of permanent disability.

Mild arthritis was a complicating factor in traumatic lesions of the cartilage and similar minor lesions.

There were sixteen cases of gross laxity, but in assessing the effect of this factor, all but five cases were discarded, due to the coexistence of one or more other complications. In thirteen of these cases, the laxity was anteroposterior, solely or predominantly. Of the cases with well-marked laxity, 42 per cent. also had definite arthritis of mechanical origin; while 8 per cent. of cases without well-marked laxity had this type of arthritis.

A severe postoperative effusion in one case in the series led to the formation of a sinus, which discharged sterile fluid for three weeks. In another case, passive flexion administered by a new masseur caused rupture of the suture line in a joint already overdistended with fluid. Our present routine is to apply three or four thick sheets of sterile cotton wool around the limb from mid-calf to mid-thigh, with a six-inch bandage to compress each layer of wool separately and firmly.

The penalty of delay varies with the type of tear. In the following case, the erosive effect of what originally was, in all probability, a taglike tear was considerable.

CASE 59. The patient was thirty-one years old. Operation was performed after a delay of six years. The medial meniscus was found to have a complete tear, somewhat transversely at its middle; the edges were rounded off, showing it to be an old lesion. The posterior half could not even be seen. There was extensive osteo-arthritic lipping of all articular surfaces; extreme erosion of the articular surface of the femur extended down to the center of the bone in the center of the condyle. Through a separate posterior incision the back half of the meniscus was removed. There was disability of 15 per cent.

On the other hand, the following case in which a bucket-handle tear was found, shows the effect of less frequent traumata.

CASE 5. The patient was twenty-five years old. There had been a two-year period of delay, during which time the knee "had been out on several occasions". There was roentgenographic evidence of early arthritis. At operation no damage to the articular cartilage was found, but the synovial membrane was injected. Three months after the operation, there was well-marked joint crepitus. Disability was assessed at 2.5 per cent.

The patients in the top age group (forty to fifty years) did not fare quite as well as did the patients in the lower age group. One patient received compensation; the average disability per capita was 0.4 per cent.; and the average number of days off work after operation was fifty-two. Certain older patients showed preoperative evidence of arthritis,—one slightly, and four moderately. The youngest patient in our whole series was seventeen years old, and he recovered in twenty-six days, although the average recovery time for his age group was forty-eight days.

COMPENSATION

Compensation assessments were normally made after the man had been continuously at work for two months after operation. All claims were then settled. By law the man is entitled to later apply for re-examination and re-assessment, if he feels that the knee condition has deteriorated. Although four years have now elapsed since the last patient in this series resumed work, there have been no applications for increased assessments.

Of the 100 cases, twenty-seven men received some compensation, varying between 2.5 per cent. and 15 per cent. The average for the whole series was 1.6 per cent. Because an empirical standard is usually set by current practice in non-scheduled assessments, the following illustrative cases are given to show the broad basis used for comparison.

Assessment of 2.5 per cent.

CASE 35. An "occupation fitter", thirty-four years old, had spent two years underground. Ninety days after the injury there was wasting of seven-eighths of an inch. At operation for removal of the left medial meniscus, there was no evidence of arthritis. The patient failed to report for work for sixty-eight days after operation. Four and a half months after operation, he complained of tiredness in the leg after working, and there was wasting of one and a quarter inches. The patient had not missed a shift since resuming work. There was full range of motion, no ligamentous laxity, no effusion, and no crepitation. There was a diagnosis of quadriceps insufficiency, and it was decided that the patient was a lazy fellow.

Assessment of 10 per cent.

CASE 83. The patient, a painter, thirty-three years old, worked above ground, and showed moderate laxity of the medial collateral ligament. Mild osteo-arthritic changes were evident at operation for removal of the right lateral "bucket-handled" meniscus. Two incisions were made, since the diagnosis of a lesion of the medial meniscus proved incorrect. A low-grade infectious arthritis followed operation, and the patient failed to report for work for fifty-one days. The disability assessment was made after one month at work, when the patient stated that he had "pain at the end of a day's work, but not in the morning". There was then moderate joint crepitation, gross laxity of the anterior cruciate and medial collateral ligaments, one inch of quadriceps wasting, full range of movement, and no effusion.

Assessment of 15 per cent.

CASE 59. The patient had been an underground stoper for twelve years. He was thirty-one years old. There was gross laxity of the anterior cruciate ligament, and wasting of two and a quarter inches of the quadriceps. The knee had troubled the patient for 178 days previous to the operation. Roentgenographic evidence of extensive osteo-arthritis was confirmed at operation, and there was crepitation of both the patellofemoral and main joints. Transverse tears of the medial meniscus and of the posterior horn were evident. There was erosion of the cartilage down to the bare bone of the medial condyle, and complete rupture of the anterior cruciate ligament. The patient did not resume work for eighty-nine days after the operation. Five months after the operation, he stated: "My knee is sore if I walk some distance; at night there is a dull pain." At examination, well-marked joint crepitation was evident, as well as gross instability of the anterior cruciate ligament. There was one inch of quadriceps wasting, full range of motion, and no effusion.

SUMMARY

1. An analysis has been given of 100 consecutive knee arthrotomies performed on European miners working underground in the Witwatersrand Gold Mines.

2. The routine of clinical diagnosis, operation, and postoperative care has been described.

3. The operative findings have been analyzed. In four cases, no meniscal lesions were discovered at operation; in eighty-two cases, tears of the medial meniscus were found; in nine cases, tears of the lateral meniscus were seen. There were double tears in three cases, and discoid menisci in two. Of ninety-seven torn menisci, forty-nine were of the bucket-handle type.

4. The operative findings have been correlated with the signs found at examination.

   a. Pain at the anteromedial joint line was found to be of considerable diagnostic significance. Absence of such pain contra-indicated arthrotomy for meniscal lesion.

   b. It was shown that locking is frequently, but not always, due to a meniscal lesion. A stub of anterior cruciate ligament was the cause of locking in one case.

   c. Meniscal damage may exist in the absence of wasting.

   d. Fouché's "hot spot" on the medial facet of the patella is described.

   e. The "crushing sign" is found to be not entirely pathognomonic of meniscal damage.

5. Erroneous diagnoses have been analyzed in some detail.

6. The end results of treatment are given, with disability assessments averaging 1.6 per cent. for the whole series.

7. Complications of the operation have been discussed.

8. The penalty of delay in operation has been found to vary greatly according to the type of lesion.

9. The findings in our investigation favor early and total meniscectomy, once an incontrovertible diagnosis has been made.

TRAUMATIC DEGENERATION OF THE ARTICULAR CARTILAGE OF THE PATELLA

BY LIEUTENANT COLONEL RALPH SOTO-HALL
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The frequency of arthrotomies, performed for the treatment of various types of internal derangement of the knee, has focused attention on lesions of the articular cartilage of the patella in military personnel. It is surprising that pathological changes at this site, which have such a high incidence, and which seem to play such an important rôle in the persistence of symptoms after knee surgery, have received so little attention in the Anglo-American literature. Scandinavian authors have written extensively on this matter during the last few years.[3,4,5,6]

The patella lies in one of the most exposed parts of the body. It has an extremely thick cartilage, the central part of which is poorly nourished. This articular cartilage may suffer either acute or chronic traumatization, leading either to fractures or to delayed changes, which we have interpreted as a result of impaired nutrition.

PATHOGENESIS

While studying amputation specimens obtained after severe injury, we have observed at times recent linear fractures of the articular cartilage without accompanying bone injuries, although careful roentgenographic studies of these specimens did not demonstrate any pathological changes. Such cartilage injuries (similar to those frequently noted in the capitellum of the humerus [capitulum humeri] during the operation for excision of a fractured head of the radius), though usually not clinically demonstrable, may lead to the formation of loose bodies, or to the impairment of the gliding mechanism, with slow disintegration of the cartilage from attrition; this may explain in part the partial fixation of the patella after certain fractures of the femur. Moreover, in the specimens studied, there was often a tearing of the capsular attachment to the patella, which probably resulted in damage to the rather limited blood supply.

Thus, from the direct injury, or from a secondary loss of adequate nutrition, or both, there occurs a pathological state in the cartilage of the patella, which has been designated as chondromalacia patellae or, less appropriately, chondritis (chondropathy). The frequency of this condition can be illustrated by the fact that in sixty-five arthrotomies performed in a military hospital for chronic knee complaints, this lesion of the patella was encountered in twelve cases, representing 18.5 per cent. In six of these patients, the degeneration and erosion were so extensive, and the disability was so pronounced, that total excision of the patella was warranted. The incidence is highest in young adults, the average age in this series being twenty-nine, and the age of the oldest patient, thirty-six years. (We have seen this condition well advanced in a young woman of seventeen, whose case is not included in this study.) This average age may be influenced, of course, by the age of the military personnel, but in our civilian practice we rarely encountered a similar lesion in older individuals.

HISTORY

All patients gave a history of moderately severe trauma,—consisting in six cases of direct contusion; in three, of a twisting injury; and in one, of a linear fracture of the bone. Two had suffered dislocations of the patella, followed by recurrent subluxations. These two patients are of particular interest because, in addition to the lesions in the cartilage of the patella, small loose bodies and an area of advanced cartilage erosion were found on

the lateral femoral condyle, exposing the subchondral bone for about one-half inch. This is a frequent concomitant finding in recurrent dislocation of the patella, and results from repeated trauma and severe friction as the patella rides over the condyle. It should be taken into consideration when corrective surgical procedures are planned. Wiberg, in 1941, described well-advanced chondromalacia in recurring dislocations of the patella, with and without an accompanying congenitally low femoral condyle, and it was noted after dislocation of the patella experimentally by Bennett, Bauer, and Maddock, during their study of repair of articular cartilage in the femur.

The clinical histories followed a somewhat typical pattern. After the original injury, there was a short period of total disability, which was followed by a rather quiescent period of several months in which there were some mild symptoms in the knee. With or without an additional precipitating injury, there was then a gradual development of more severe symptoms, culminating after some months in a marked disability. The course of this syndrome simulates, therefore, the sequence of events seen in post-traumatic aseptic necrosis of bone, when it occurs in various parts of the body.

A typical history is the following:

CASE 6. A soldier, twenty-three years old, with approximately two years' service, was first injured in 1937, when the anterior part of the right knee was struck. The patient believes a diagnosis of ruptured ligaments was made, and he spent six weeks in traction, and six months on crutches. Following this, he was able to engage in baseball, basketball, and boxing, with no disability, but with an occasional feeling of impairment, discomfort, and instability in the knee. He entered the Army on August 3, 1942, and underwent the strenuous basic training without difficulty. He was assigned to an engineering unit, and became a jeep driver. In March 1944, while on shipboard going overseas, he was engaged in an exhibition boxing match and twisted the knee. Pain and swelling developed, for which he was hospitalized; his condition did not improve, and it was necessary to return him to the United States. His symptoms consisted of loud popping sounds in the knee, a feeling of instability, and pain located deep in the joint. Examination showed atrophy of one inch at the mid-thigh, although the patient walked without a limp, and had a normal range of motion. When he sat with the knee at 150 degrees of extension, the patella could be displaced laterally, and hooked on the lateral condyle so that it remained in this position. Marked crepitation could be felt under the patella. No effusion was found; a minimal relaxation of the tibial collateral ligament was noted. At operation, the patellar articular cartilage was found extensively involved (Fig. 1), and on the lateral femoral condyle was an area of cartilage erosion, similar in size to that of the patella.

FIG. 1

Case 6. Soldier, aged twenty-three. Operation disclosed extensive involvement of medial facet of the patella, with loose-body formation. A well advanced "mirror image" was also present in the lateral femoral condyle. This type of lesion is produced by recurrent trauma between the lateral condyle of the femur and the patella, resulting from a muscle imbalance in the quadriceps which produces recurrent slipping.

SYMPTOMS

One of the most significant symptoms is that of crepitation associated with certain active movements of the knee, although this may be absent when the disease in-

volves only the most inferior part of the cartilage. Crepitation is not always elicited when the knee is flexed with the patient sitting, and we have found it of value to test the patient in the following manner: Lying upon his back with the hip and knee flexed, the patient is asked to flex and extend the knee gradually without moving the hip. This movement, by its various anatomical relationships, is an assurance that the diseased area will come in contact with the femur. The crepitation can be easily felt by the examiner after he has placed his hand upon the affected knee, and forcibly pressed the patella against the femoral surface. This test is of particular value in the mild and early cases. Crepitation is significant also in those cases where there is instability, due to relative inequality of power between the vastus lateralis and vastus medialis, since in the presence of such imbalance the patella does not follow the intercondylar groove, but impinges against the lateral condyle of the femur. The importance of this imbalance of the patella was demonstrated as early as 1867 by Duchenne who, by applying a strong electrical stimulation to the vastus lateralis, was able to produce outward luxation of the patella, while with stimulation of the vastus medialis, no medial displacement of the patella could be produced. This lateral displacement is explained by the fact that, when the vastus lateralis contracts, due to its axis of pull, it tends to draw the patella outward. In the normal individual this deforming force is countered by the lowermost fibers of the vastus internus, which lie in an axis almost transverse to it. Because instability of the patella may exist in the patient, which may otherwise escape detection, it is important to examine the patellofemoral joint in active motion. Roentgenographic studies of the specimens, as well as various projections of the patella itself have generally failed to show any demonstrable change in the patella. However, by taking axial views of both knees in 60-degree, in 90-degree, and in full flexion, we have been able to demonstrate the abnormal course of the patella as it moves from its central position to be lodged in the intercondylar groove.

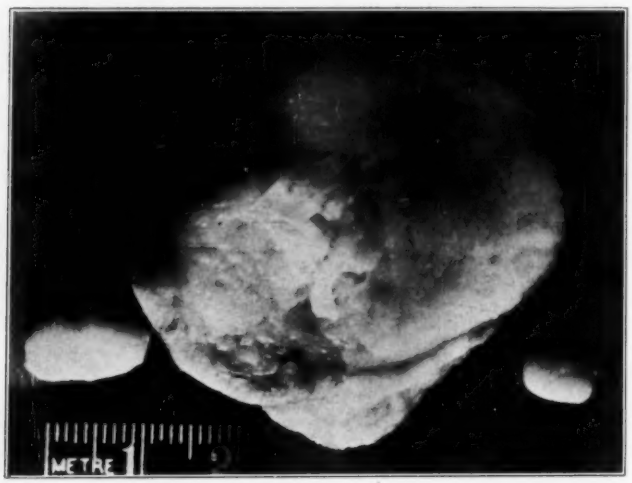

FIG. 2

Case 1. This patient, aged twenty-eight, reported symptoms dating back six years to a football injury. He presented laxity of the capsule with recurrent subluxations of the patella and loose-body formation. A very small lesion was present in the lateral femoral condyle.

It is of interest that the patient often has difficulty in describing and localizing the deep-seated pain, a factor which, combined with the pseudolocking or ratchet movement of the knee, often leads to diagnostic confusion. Of the twelve proved cases, four patients had been previously operated upon elsewhere for suspected meniscal injury, but the inaccuracy of the diagnosis was proved by the persistence of identical symptoms and by the subsequent operative findings.

The diagnosis must finally rest on combinations of these signs and symptoms:

1. Subpatellar crepitation on active movement;
2. A variable deep-seated pain;
3. Tenderness on percussion of the patella;
4. A pseudolocking, or ratchet rhythm;
5. A subjective feeling of instability;
6. Occasional recurrent subluxations of the patella.

PATHOLOGY

A review of the various stages in the gross pathology of chondromalacia readily explains the clinical picture. The initial change, soon after trauma, is oedema of the articular cartilage, followed by a certain amount of softening, with subsequent formation of rather characteristic fissures or cracks. (The softening can be demonstrated during arthrotomy by passing a blunt instrument gently over the diseased surface, when a soft indentation can be felt.) That part of the patellar cartilage which is most poorly nourished, the central and medial area, is often the site of the most serious involvement. As fraying of the cartilage and degeneration progress, the fissures develop small fine tufts which remain attached at one end or, more rarely, become free loose bodies (Fig. 4). In the later stages, the subchondral bone is exposed at the base of the irregularly shaped craters, showing its bluish polished surface, in vivid contrast to the adjacent white glistening cartilage. When the disease has been present in the patella for a long period of time, a similar condition develops in the opposing surface of the femur. This secondary lesion may assume the identical size and contour of the parent lesion, and we have termed it a "mirror image", because of its similarity in appearance. Two types of "mirror image" have been observed; one on the lateral femoral condyle, found in those cases presenting subluxations of the patella, and another lying directly between the condyles (Fig. 5), the etiology of which is more difficult to explain. As these small craters in the joint surfaces glide over each other in apposition, they produce the feeling of insecurity, pseudolocking, and the ratchet rhythm.

Chondromalacia has been considered by many to be simply a manifestation of hypertrophic arthritis; but its very isolated location in the joint, its frequency in young people, and the absence of arthritic changes in other articulations, point rather to a traumatic origin with secondary mechanical irritation of the joint. It is possible, of course, that this condition initiates what in older patients presents itself as a degenerative patellofemoral arthritis.

TREATMENT

In early cases, the treatment of traumatic degeneration of the articular cartilage of the patella should consist of protection of the joint from further trauma, and of the use of physical therapy, the basis of which should be mainly development of the extensor mechanism by active exercises with and without resistance. Many patients present little disability, if the area involved is small and the lesion quiescent, and if the patella glides within its normal depression in the intercondylar area. Once the symptoms have become chronically disabling, however, only radical surgical procedures can bring relief, and the following operations have been suggested for the cure of this condition:

1. Resection of the abnormal cartilage;
2. Total resection of the articular surface;
3. Patellectomy.

When the pathological changes are very limited in size and degree, the cartilaginous irregularities can be trimmed and smoothed down by careful dissection with a sharp knife, and the irregular borders of the craters can be beveled. This débridement has some value, and should be a routine procedure in the smaller lesions. But when the cartilage degeneration is more widespread, the problem is more difficult. Total resection of the articular cartilage, although recommended, has been done only once by this author, and then without relief of symptoms, a patellectomy being necessary at a later date; nor did two other patients, on whom the same operation was performed by other surgeons, show any improvement.

In those patients presenting extensive degeneration with incapacitating symptoms,

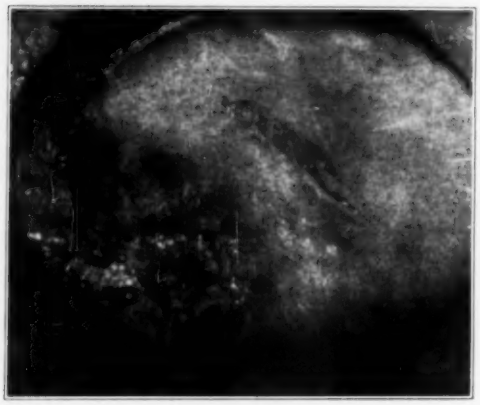

FIG. 3

Case 2. Lesion produced by instability of the patella.

FIG. 4

Case 3. Specimen from patient, aged twenty-seven, showing well-advanced fissures and tuft formations.

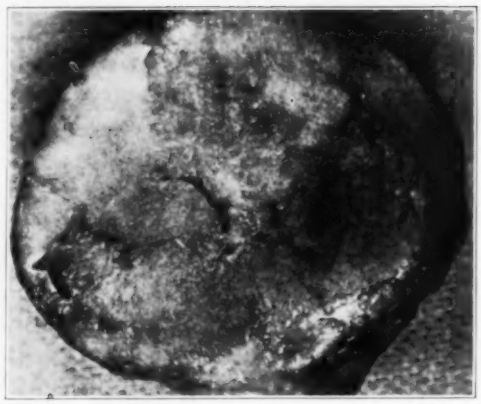

FIG. 5

Case 4. Specimen from patient, aged thirty-six. Advanced changes, showing fairly large area of exposed subchondral bone, are evident. This man presented a large "mirror image" in the intercondylar area of the femoral articular cartilage.

total excision of the patella should be considered. We have removed the patella in six such cases; all six of the patients had been prevented from performing their regular duties by the condition of their knees before the operation. Two of these obtained excellent function; two showed marked improvement and the results could be considered good, with a reduction of pain and absence of annoying crepitation. The last case is too recent for evaluation. One result could be classed as poor, presenting no improvement in function; this patient had a history of symptoms in the affected knee, extending over a period of ten years, and the femoral condyle presented a well-advanced "mirror image". The prognosis appears less favorable in cases showing involvement of the femoral condyle, a factor which should be kept in mind in considering early intervention.

Among technical considerations in patellectomy, certain points should be mentioned, as failure to observe them can lead to a residual derangement in function. We have approached the patella in later cases by a cup-shaped incision. The quadriceps expansion is incised in the same manner, so that the incision passes over the level of the inferior third of the kneecap. This tends to bring the suture line of the tendon in the area of the fat pad, rather than in the line of the femoral condyles. The quadriceps tendon is carefully removed from the patella by a meticulous sharp dissection. This results in an actual lengthening of the tendon, which should be corrected if the essential requirements of proper tension in any tenoplastic operation are fulfilled. This correction is made by overlapping the tendon about one-half inch (1.25 centimeters), so that proper tension is maintained; when this has been done, complete active extension will be regained more rapidly following the operation. By extending the medial arm of the incision somewhat higher and removing a V-shaped section, balance between the vastus lateralis and vastus medialis can be restored. This last step in the procedure should be reserved for those cases in which instability of the patella has been demonstrated.

It is of considerable importance that good muscle control should be taught the patient

by careful instruction *before* operation; and gentle quadriceps contractions should be resumed three or four days after the operation. Two weeks after the institution of active movements, a resistive exercise should be introduced, in order to develop the quadriceps. The resistance in the last 15 to 20 degrees of extension is particularly important, as this develops the vastus internus. All patients in this series regained normal extension by following this routine.

DISCUSSION

The clinical picture of chondromalacia with imbalance of the patella is often puzzling and deceptive, simulating other internal derangements of the knee. Because of this, in all knee arthrotomies it is obligatory that, through an adequate incision, a routine inspection of the joint be carried out; and this should include correct visualization of the cartilage of the patella, which can only be done while the knee is in extension, because in this position the quadriceps tendon is relaxed, allowing free mobility of the patella. The tension of the tendon during flexion is a serious objection to performing an arthrotomy through its entirety, with the knee in the flexed position, commonly used for excision of the menisci.

The impression should not be obtained that patellectomy is recommended in a large number of cases. Only those in which an extensive destructive and progressive lesion can be clinically demonstrated should be considered for this operation. In each case conservative methods of treatment must be given a thorough trial, before any radical measures are advocated.

Traumatic degeneration of the articular cartilage of the patella is of considerable clinical importance. It may result from nutritional impairment, following such common injuries as severe contusions, sprains, or fractures, or it may be produced by chronic traumatization, resulting from abnormal mechanics in the patellofemoral joint.

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PNEUMARTHROGRAMS OF THE KNEE

A Diagnostic Aid in Internal Derangements *

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The rugged strain of jungle combat, beach landings, marches of twenty to thirty miles, obstacle-course and unarmed training, produces a high incidence of the acute injuries of the knee joint, seen in our General Hospital. In addition, many remote "football" and "trick" knees that had been quiescent in civilian life soon become disabling under conditions of combat, with recurrent episodes of pain, effusion, and locking of varying severity. The history and clinical signs in many of these cases, though usually sufficient to make a diagnosis, are all too frequently not clear-cut, and, on occasion, are frankly misleading.

Schaer has estimated the incidence of errors in knee-joint diagnoses in his clinic as 15 per cent., and the authors regard this as conservative. In an attempt to evaluate our clinical errors in 101 cases requiring operation, we have classed or graded the preoperative diagnoses made by all our ward officers as follows:

Class A.	Entirely correct	37 per cent.
Class B.	Partially correct	42 per cent.
Class C.	Misleading	21 per cent.

In an effort to raise our percentage of correct diagnoses in borderline cases, we undertook the development of a technique for the roentgenographic visualization of the complicated intra-articular structures of the knee joint, since ordinary roentgenograms furnish little significant information.

To study the effect of a soluble radiopaque contrast medium, six fresh postmortem knee joints, prior to roentgenography, were filled with solutions of sodium iodide, varying in concentration from .25 to 8 per cent. The results were uniformly disappointing, as bone detail was obscured, and outlines of the menisci were indistinct.

Radiolucent contrast media proved much more satisfactory. The results with oxygen and the technique to be described have been especially gratifying. We consider oxygen ideal because of its availability, non-irritating quality, and fairly rapid absorption from the joint space. On a busy Service it has been a time-saving procedure to allow the oxygen to become absorbed from the joint during forty-eight hours of enforced bed rest following pneumo-arthrography. If the gas is to be aspirated following the x-ray examination, air, which is absorbed more slowly, serves just as well. Australian surgeons have used oxygen and carbon-dioxide mixtures with equal success.

Inflation of the knee joint with gas prior to roentgenography has been reported by a number of authors, as pointed out by Quaintance. One of us (W.H.M.) had the privilege of hearing a paper by Evans, who suggested that the knee joint be spread before taking roentgenograms. The modification and combination of these methods, together with helpful suggestions from many sources, have aided in the development of a technique which has yielded gratifying results in supplying diagnostic information not previously obtainable.

While, in 508 pneumarthrograms of the knee, no serious complications have been observed, we wish to call attention to the fact that fatal air emboli have been reported, following air injection in urological cases. Rettig, from a survey of the literature, reports four fatal cases in bladder injections. The fatalities were thought to be due to amounts of air in excess of ninety cubic centimeters. The same author also reports one case (described

* Read at the meeting of American and Australian Surgeons, Brisbane, Australia, December 12, 1943.

by Goldenberg) in which pneumopyelography was fatal, but quotes several other authors who report no fatalities or serious complications.

We have had no serious complications. One patient became faint for a short while upon sitting up, after the roentgenograms had been taken. Subcutaneous emphysema is occasionally seen, but has been without clinical significance. We have been very careful not to inject oxygen into the knee joint under forced pressure.

TECHNIQUE

To obtain roentgenograms that are worthy of interpretation, great care must be taken at each step. Hearty cooperation between the roentgenologist and the surgeon prevents disappointments, which were so common when ordinary methods were used.

Step 1. Inflation of the Joint

This is done with 1 per cent. procaine infiltration under strict aseptic precautions in the operating room (Fig. 1). A 20-gauge or 22-gauge needle is inserted into the lateral infrapatellar joint space. This is easily accomplished in the presence of increased synovial fluid, which should be carefully aspirated. In the absence of effusion, entry is facilitated by strongly displacing the patella laterally with one hand, while the needle is inserted into the sulcus formed between the patella and the lateral condyle of the femur (Fig. 2). Extrasynovial injection is carefully avoided, as it may impair or ruin the value of the procedure. When necessary, it is done by carefully directing the needle under the patella instead of into the loose fatty areolar tissue in the floor of the suprapatellar pouch, and by testing the free passage of gas back and forth through the needle and syringe. The joint is then *gently* distended with oxygen to the limit of comfort, usually requiring from 80 to 120 cubic centimeters. After the needle has been removed, a finger is kept pressed to the puncture wound for a few seconds after inflation, and the skin is then sealed with collodion.

One point of diagnostic significance can be elicited during the inflation of the joint. As intra-articular pressure increases, it reproduces the pain of any recent capsular or ligamentous sprain which is well localized to the particular structure damaged; but this pressure has no localized painful effect on a meniscal lesion or any other internal derangement.

Step 2. Localizing the Joint Space

The surgeon should mark the joint space accurately on the skin with ink or pencil, so that it can be seen in the positions of both the postero-anterior and anteroposterior roentgenograms. Some technicians are in the habit of centering the tube over the middle

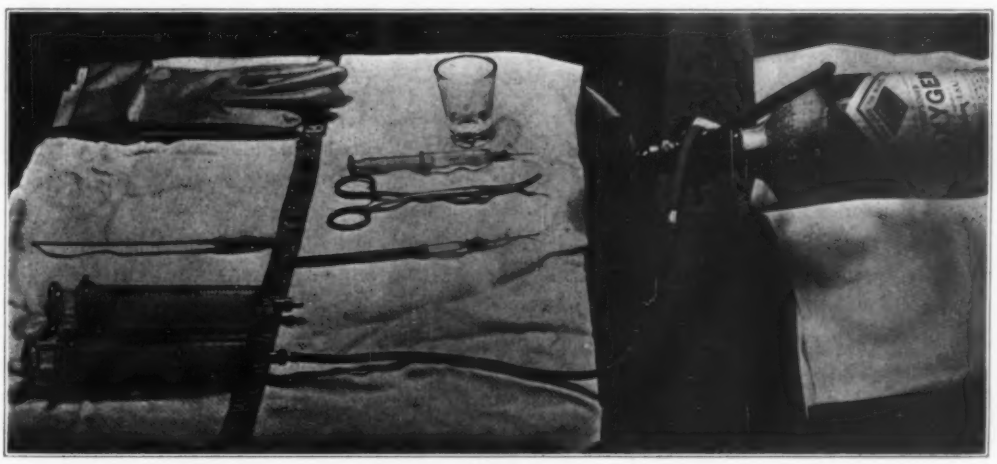

FIG. 1
Equipment for pneumarthrogram.

of the patella. This does not give a satisfactory profile view of the menisci or of the joint space. If there is an overlap of the femoral and tibial condyles on the plate, the meniscal shadow may be difficult to follow, and the view should be retaken. There is a slight individual variation in the plane of the tibial plateau which may require recentering of the x-ray tube by a careful technician, if the angle of the rays is not satisfactory.

After the skin has been marked,

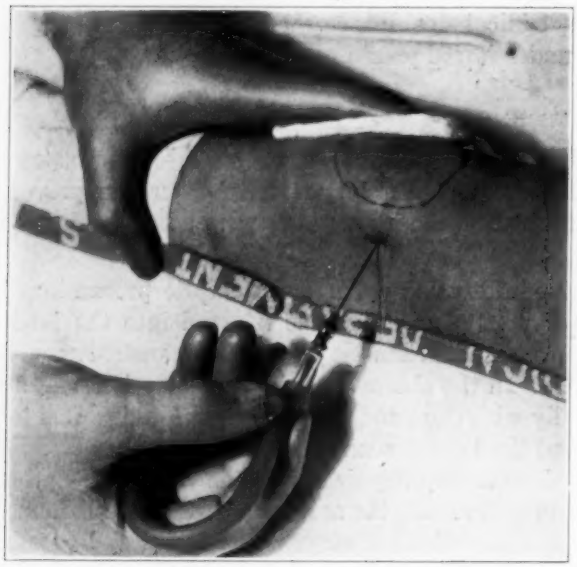

FIG. 2

Needle being inserted into sulcus between patella and lateral condyle of femur.

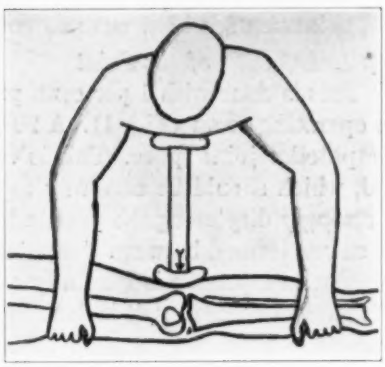

FIG. 3

Spread of medial joint space.

the patient is placed in the *prone* position on a cart, before being taken to the x-ray room. This position and pressure on the suprapatellar pouch encourage the spread of the gas throughout the joint, and allow the fluid, if any, to gravitate into the suprapatellar pouch.

Although Cullen and Chance advise localizing the joint space fluoroscopically, we have not found this necessary as a routine procedure.

Step 3. Spreading the Joint Space

This is the most important step in taking satisfactory pneumarthrograms; and, if it is not carried out carefully, the value of the whole procedure is greatly reduced. The method is shown in the diagram (Fig. 3) of the technician and patient during the exposure of the x-ray film. The technician, properly protected, should sit on a low stool with a padded wooden bar held between his chest and the patient's knee joint. A lead arrow marker and sponge rubber are fixed to the knee end of the bar to show where the pressure has been applied. The technician exerts counterpressure through both hands, one around the ankle and one around the upper thigh. The opposite side of the knee joint is then levered apart by a steady, even, but strong pressure with the bar, and a simultaneous pull with his arms. After ten to fifteen seconds, the patient relaxes sufficiently to allow proper spreading. Then, at a signal, the exposure is made by another technician who has centered the tube accurately.

A mechanical device for spreading the joint can readily be constructed, as suggested by West. It consists of a bar with wide straps at either end to go around the thigh and the ankle, and a screw clamp through its center to apply pressure to the joint. We have found this to be of great value when we have had to use a portable x-ray unit. These two methods have been more satisfactory in our experience, than that recently mentioned by Somerville, in which the x-ray tube is pointed in a vertical direction, necessitating turning the patient on his side to take the anteroposterior or postero-anterior view.

Step 4. Roentgenographic Technique

The exposures are made with a fine-focus (two-millimeter) tube fitted with a cylin-

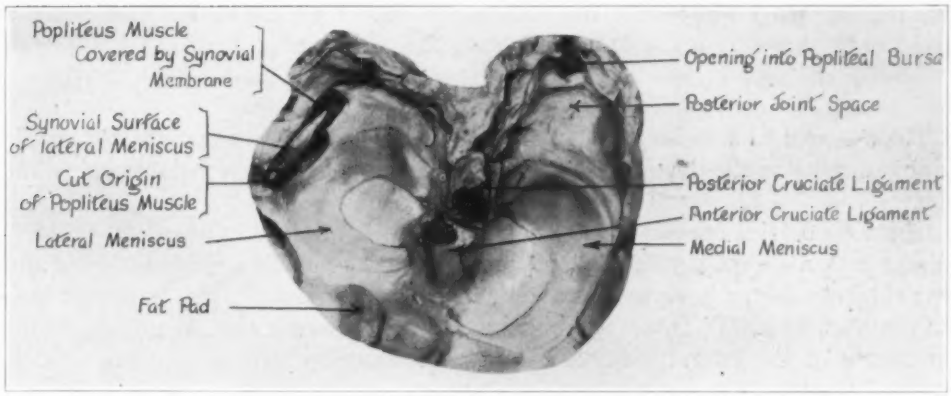

FIG. 4
Dissection of knee with femur removed.

drical cone, eight centimeters in diameter. The technical factors are as follows: a distance of thirty-six inches, average of fifty-five kilovolts, thirty milliamperes, and exposure of two-tenths of a second, with a par speed screen.

Five plates are taken as follows:

1. Postero-anterior view with spread of the medial joint space;
2. Postero-anterior view with spread of the lateral joint space;
3. Lateral view with the knee slightly flexed;
4. Anteroposterior view with spread of the medial joint space;
5. Anteroposterior view with spread of the lateral joint space.

The first three plates are usually the most valuable. In addition, oblique views may be taken, as suggested by Cullen and Chance, but it should be remembered that the anterior and posterior tips of the menisci cannot often be visualized, as their attachments are obscured by the tibial spines. However, it is unusual to encounter fractures of the menisci which are not visualized in these five routine views. Most tears of the cornua of the menisci will show some distortion of the center of the semicircle, which is routinely thrown into profile.

To obtain uniform results the knee is held in slight internal rotation for spread of the medial joint space, and in slight external rotation for spread of the lateral joint space. This is reversed, if a lesion of the posterior portion of a meniscus is suspected.

The oxygen may be allowed to escape through a needle reinserted into the procaine wheal; then the patient's activities are not restricted. Our usual practice, however, is to keep the patient in bed for forty-eight hours during which time most of the oxygen is absorbed. No postinflation medication has been required in any case. During pneumo-arthrog-

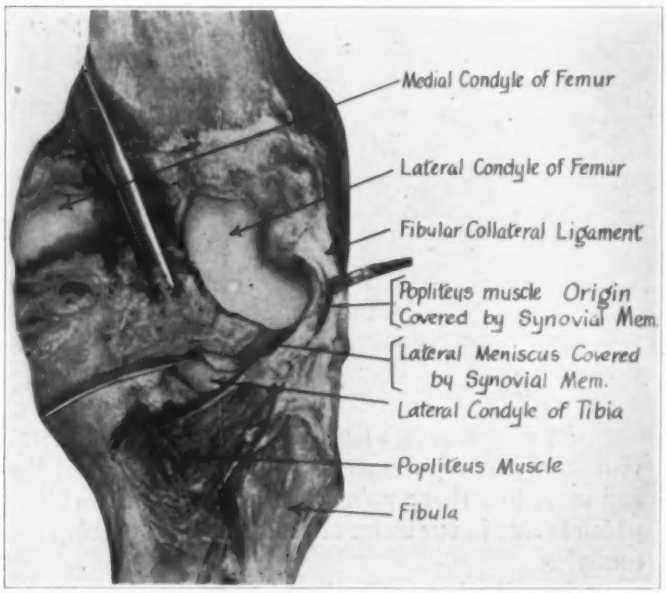

FIG. 5
Posterolateral dissection of the knee.

raphy on his own knee, one of the authors (W.H.M.) experienced a mild sensation of warmth in the knee for a few hours following the procedure.

ANATOMY

The anatomical attachments of the medial meniscus are so complete and simple that any abnormality in the pneumarthrograms of the medial side is a reliable indication of a lesion.

The lateral joint space with the popliteus muscle and the free portion of the lateral meniscus presents a much more difficult problem, and a correct interpretation of the confusing shadows demands an understanding of the variable anatomical relationships. Four fresh postmortem knee joints were dissected, and particular attention was directed to the attachments of the lateral meniscus and its relationship to the popliteus muscle and synovial folds (Fig. 4).

The popliteus muscle originates from a groove in the lateral epicondyle of the femur, just beneath the femoral attachment of the fibular collateral ligament (Fig. 5). This portion of its origin may be completely intra-articular, if the bursa between it and the collateral ligament communicates with the joint. As the tendinous origin of the muscle courses down obliquely across the posterior joint space, its outer edge is more or less fused with the posterolateral capsule of the knee. Its inner aspect, however, forms a distinct ridge covered by synovial membrane, and, as it passes downward, backward, and medially, lies in a groove in the upper edge of the tibial condyle.

The lateral meniscus has no peripheral capsular attachment where the popliteus muscle crosses it, and here the base of the meniscus is covered with synovial membrane. This explains the frequent vertical and normal oblique shadows in the lateral joint space in the pneumarthrograms, which, if seen on the medial side, would represent tears of the meniscal attachment.

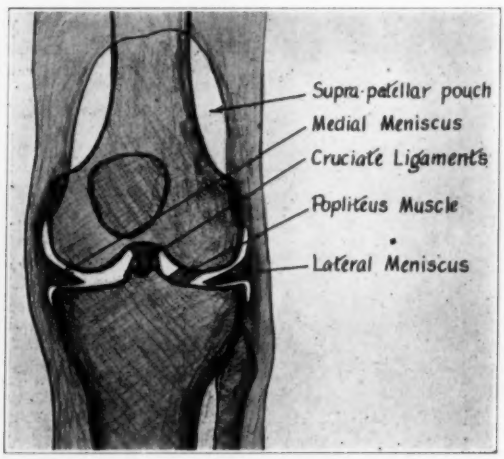

FIG. 6
Diagram of postero-anterior pneumarthrogram.

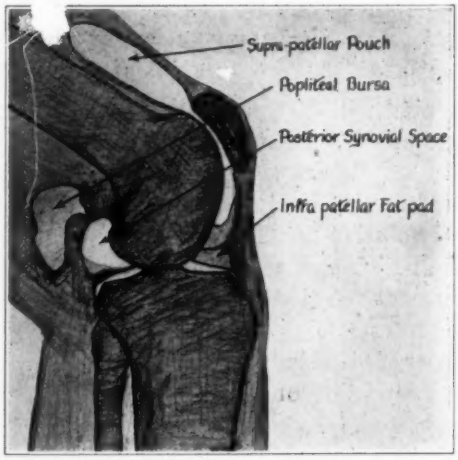

FIG. 7
Diagram of lateral pneumarthrogram.

INTERPRETATION

The diagrams in Figures 6 and 7 represent the anatomical structures which can be visualized in the pneumarthrograms. The edges of the normal menisci should be smooth and come to a sharp point. These details can be obscured by fluid and bubble formation, which is rare in our series of cases, or by an overlap of shadows of the tibial and femoral condyles.

The following outline lists briefly the types of abnormalities that may be recognized in an acceptable film.

The Menisci

Many fractures, tears, and dislocations are clearly shown by abnormal shadows, such as:

a. *Irregularity* in contour of either the femoral or tibial surfaces shows tears or shredding.

b. *Blunting or shortening* of the sharp edge indicates small tears or lesions of the cornu that distort the center of the meniscal shadow.

c. *Body or basal shadows* (in the absence of emphysema) show tears without displacement. These are of great significance in the medial meniscus, but much harder to interpret in the lateral meniscus.

d. *Partial or complete absence* of the meniscal shadow always indicates either a dislocation or a previous surgical removal.

e. *Abnormal sizes.* Meniscal shadows that are too long are "discoid". Those that are too broad are due to cystic changes of the menisci.

Synovial Cavities and Bursae

1. *Suprapatellar*
   a. A diminished capacity usually indicates previous inflammation or long immobilization. However, fibrous septa are normal and frequently found.
   b. Space-occupying lesions or non-calcified tumors are usually well outlined. However, small bodies are often not visualized.
2. *Infrapatellar*
   a. A diminished anterior joint capacity indicates the size of the fat pad, which may be larger than normal due to trauma, and may be the seat of hemorrhage, contusion or thickening, and fibrosis.
   b. The density of the tissue of the infrapatellar fat pad frequently suggests oedema or fibrosis, and may permit the diagnosis of hypertrophy.
   c. Abnormal contour of the fat-pad shadow is often suggestive of severe tearing and contusion. At times, rupture of the ligamentum mucosum can be recognized.
3. *The two posterior pouches:* We are too inexperienced to explain abnormal conditions here, although unusual shadows can be seen. We have suspected rupture of the popliteus muscle on occasion, but have never verified the suspicion.
4. *Popliteal bursae* communicate with the posterior pouches in 14.4 per cent. of our 508 pneumarthrograms. These are not considered to be of clinical significance, unless the history and physical findings point definitely to a Baker's cyst or popliteal bursitis.

Articular Surfaces

Patella: We have found that unusual sclerosis, slight irregularity, and cupping of the articular surface of the patella are associated with varying degrees of chondrosis, so that at operation we have noted roughening, softening, fibrillation, and shredding of the articular cartilage. These changes are frequently unrecognized causes of internal derangement of the knee.

The condyles of the femur and tibia: Chondrosis of these weight-bearing surfaces can be seen, if extensive, and it is associated with the usual signs of arthritis.

Osteochondritis dissecans is ordinarily recognized very readily in the pneumarthrograms, with a clearer indication of the extent of the lesion than in the plain roentgenogram.

Ligamentous Structures

The laxity of the collateral ligaments is indicated by the amount of separation of the femoral and tibial condyles, as seen on all postero-anterior and anteroposterior views. Some degree of lateral instability is a common finding in many of these cases.

FIG. 8-A

Case 4772. Normal medial meniscus. With spread of the medial joint space, the shadow of the medial meniscus is thrown into distinct profile. This shadow appears as a smooth tapered wedge from its base or attachment to the capsular ligament. Note that both the superior (femoral) and inferior (tibial) surfaces of the meniscus are perfectly smooth, as they come to a point or sharp inner edge in profile. Compare with Fig. 6.

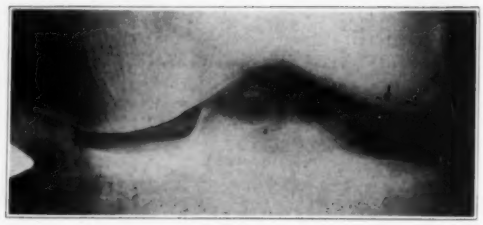

FIG. 8-B

Discoid meniscus. With spread of the lateral joint space, note the *extreme length* of the lateral meniscus which extends clear across the lateral joint space. The thinness of the meniscus in the center of the joint is indicated in this pneumarthrogram, but the tears are not visualized. The diagnosis of *discoid meniscus* could not have been made without this pneumarthrogram before operation. Compare with Figs. 6 and 9-A. This would be a normal-sized lateral meniscus if it only extended to the arrow, where the popliteus muscle shadow leaves the femoral condyle. Note the widening of the lateral joint space, indicating laxity of the lateral joint ligaments.

The shadows cast by the cruciate ligaments can at times be visualized on both the anteroposterior and lateral views, but ruptures cannot be diagnosed roentgenographically by this method.

During our first nine months' trial of this procedure, 207 cases were studied with pneumo-arthrography, and the number has now reached 508. Of the first 207 cases, 101 were operated upon, and an evaluation of their pneumarthrograms was verified by operation. The x-rays were reviewed without charts or names; then our diagnoses were checked with the operative findings, and an effort was made to grade their accuracy and value as follows:

Evaluation and check by operative findings in 101 cases:

A.	Conclusive diagnostic aid (irrespective of clinical findings)	43
B.	Limited diagnostic aid (confirming clinical findings)	40
C.	Misleading or contradictory aid (largely due to inexperience)	3
D.	Technically too poor and unsatisfactory for interpretation	15

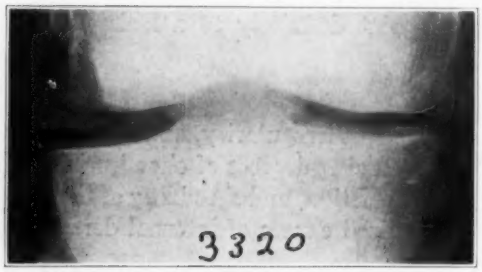

FIG. 9-A

Case 3320. Normal lateral meniscus. With spread of the lateral joint space, note the relatively thinner and longer shadow of the lateral meniscus in comparison with that shown for the medial meniscus in the previous case (Fig. 8-A). Note also that the body and surfaces of the meniscus are slightly irregular and distorted by the popliteus muscle shadow which runs down obliquely through it. This *does not* represent a tear. Note how the oxygen is squeezed out of the medial side of the joint.

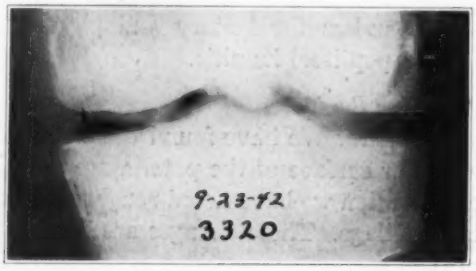

FIG. 9-B

Bucket-handle fracture-dislocation of the medial meniscus. With spread of the medial joint space, note the oblique blunted base of the medial meniscal shadow. Most of the body and inner tip of the meniscus is missing from its normal position. Compare with normal Fig. 8-A. Where a portion of the shadow of the meniscus is missing, there is always a dislocation, if the structure has not been removed surgically.

FIG. 10-A

Case 8594. Longitudinal tearing with partial dislocation of medial meniscus. With spread of the medial joint space, note the irregular shadow through the base of the ragged medial meniscus. Compare with the normal in Fig. 8-A. At operation the meniscus, which was split into two pieces with displacement of the posterior fragment, was excised. This case also had a lesion of the lateral meniscus. See Fig. 10-B.

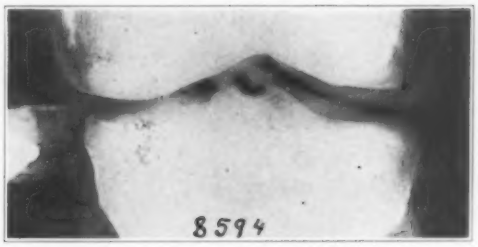

FIG. 10-B

Bucket-handle fracture of the lateral meniscus. With spread of the lateral joint space, note the absence of the tip of the lateral meniscus. This shows a definite dislocation. Note the blunted irregular portion of the base of the meniscus left attached. Compare with normal lateral in Fig. 9-A. It was excised at the same operation (Fig. 10-A). Because of the pneumarthrograms, the bilateral operation could be anticipated and planned.

We do not hesitate to eliminate films in *D* in arriving at a final diagnosis. Our ability to interpret pneumarthrograms has progressed steadily with experience and improvement in technique.

A few of the Army's overseas hospital units have made sporadic attempts at pneumo-arthrography in forward areas, but the pneumarthrograms obtained in many instances have been disappointing. Poor technique and limited facilities completely vitiated the value of this procedure. It is our opinion that pneumo-arthrography should not be attempted unless all x-ray facilities are of the best, and minute attention to all aspects of the technique is possible.

CLINICAL CASES WITH THEIR PNEUMARTHROGRAMS

Fewer than half of the patients represented by this series of 508 pneumarthrograms have come to surgery. Correct diagnosis, treatment, and proper Army disposition of the cases, whether or not operation was deemed necessary, have been materially enhanced by the information obtained by this procedure.

We are here presenting a series of cases illustrating a variety of the typical findings.

CASE 4772. This man, aged twenty-three, was admitted January 14, 1943, with a complaint of constant swelling and aching, and inability to hike for the past three months. This condition had begun during island combat. Examination disclosed increased fluid in the joint, with limitation of extension of 10 degrees, and tenderness over the lateral joint space. Pneumarthrograms (Fig. 8-A) disclosed a perfectly normal medial meniscus, while the lateral meniscus was seen to extend clear across the lateral joint space (Fig. 8-B). We were thus able to make a preoperative diagnosis of a discoid meniscus. At operation on February 9, 1943, the diagnosis was verified, and the discoid excised. The central portion of the meniscus was torn and ruffled up. On March 29, 1943, the patient was transferred to another hospital for convalescence.

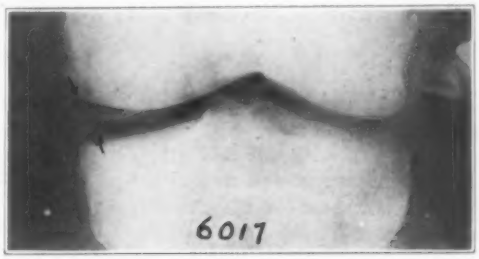

FIG. 11

Case 6017. Longitudinal tear without dislocation of the medial meniscus. With spread of the medial joint space, note the irregular oblique shadow of the tear through the base of the meniscus. The inner portion of the meniscus is distorted, but not displaced from the periphery of the joint. Compare with the normal (Fig. 8-A).

Without a pneumarthrogram we should not have been able to make an accurate preoperative diagnosis.

CASE 3320. The patient, aged twenty-seven, was admitted September 12, 1942, complaining of pain, swelling, and clicking in the right knee. He stated

FIG. 12-A

Case 2665. Normal medial meniscus. With spread of the medial joint space, the medial meniscus is visualized as a normal structure, its superior and inferior surfaces are smooth, the shadows come to a good point, and it shows a normal wedge attached to the capsule. This pneumarthrogram has not been centered properly, because the femoral and tibial condylar shadows overlap.

FIG. 12-B

Frayed lateral meniscus. With spread of the lateral joint space, note that the lateral meniscal shadow is extremely thin and its inferior surface is markedly irregular and blurred. Compare with the normal lateral (Fig. 9-A). Irregularity of the lateral femoral condyle is also suggested in this pneumarthrogram. Because of lack of confidence in recognizing this abnormal shadow, we were misled by the clinical signs on the medial side of the joint. The medial joint space was first opened at operation, but the proper diagnosis should have been made from this pneumarthrogram.

that he was first injured in April 1942, when he twisted and bumped his knee on the firing range. Examination disclosed a slight amount of increased fluid in the joint and tenderness over the anteromedial joint space. Figure 9-A shows a normal lateral meniscus in the pneumarthrograms, while Figure 9-B shows blunting of the medial meniscus and partial absence, which always indicates dislocation of that portion. At operation on October 16, 1942, a bucket-handle fracture of the medial meniscus was found, as well as mild chondrosis of the patella. The patient returned to duty on February 12, 1943.

CASE 8594. This man, aged twenty-three, was admitted May 22, 1943, with a history of three severe attacks of locking since the original injury in May 1942. Examination disclosed slight hypermobility, a small amount of increased fluid in the joint, and tenderness over the anteromedial joint space. Following pneumo-arthrography (Figs. 10-A and 10-B), the complete diagnosis of tears of both the lateral and medial menisci was made, so that at operation on June 2, 1943, both menisci were excised through two small incisions. The patient made an excellent recovery, and was discharged to duty on July 8, 1943.

It would have been impossible to make the complete diagnosis in this case from the clinical findings alone. Therefore, another operation and much time were saved.

CASE 6017. The patient, aged twenty-two, was admitted on August 8, 1943, with a history of frequent slipping and partial locking in the right knee since the original injury of falling and twisting his knee during field manoeuvres in February 1940. Examination disclosed a slight amount of increased fluid, moderate lateral hypermobility, and anteromedial joint tenderness. The pneumarthrograms (Fig. 11) confirmed the diagnosis in this case. The medial meniscus, which was found to be completely torn loose from its base and markedly shredded, was excised on August 11, 1943. The patient was transferred to another hospital for convalescence on October 5, 1943.

CASE 2665. An officer, aged thirty-three, was admitted on August 6, 1942, with a complaint of swelling, clicking, and pain on weight-bearing in the left knee, following a fall during manoeuvres on July 10, 1942. Examination disclosed distinct point tenderness over the anteromedial aspect of the joint, with increased fluid, and occasional crepitus on motion. The patient was operated upon on August 11, 1942. Because of the localized tenderness, the medial joint space was opened first, in spite of the normal appearance of the medial meniscus in the pneumarthrograms (Fig. 12-A), although the lateral meniscus, as shown in Figure 12-B, appeared very thin and irregular. The medial meniscus was normal, and the lateral meniscus was torn and markedly frayed longitudinally, but not displaced. The lateral femoral condyle also showed softening and roughening of the articular cartilage. This is one of our early cases, and is presented, because the clinical signs were entirely misleading, although the pneumarthrograms indicated the true diagnosis.

An unnecessary incision would have been avoided with more confidence in the pneumarthrograms.

CASE 5602. The patient, aged twenty-one, was admitted February 8, 1943, complaining of pain, weakness, and clicking in the left knee. Examination disclosed anteromedial joint tenderness with

crepitus and increased fluid in the joint. The pneumarthrograms (Fig. 13) disclosed an irregular tear of the medial meniscus, and the tibial half was dislocated as in a typical bucket-handle tear. The femoral surface of the meniscus appeared relatively smooth. The meniscus was excised on February 27, 1943, and the patient was returned to duty on April 28, 1943.

CASE 2922. This soldier, aged thirty-three, was admitted September 2, 1942. On August 23, 1942, while working in a kitchen, the patient had slipped on the wet floor, twisting the right knee. On admission he showed limitation of extension of 15 degrees, and anteromedial joint tenderness. The pneumarthrograms (Fig. 14) confirmed the clinical diagnosis of fracture-dislocation of the medial meniscus. This was found at operation on September 11, 1942. The patient was returned to duty on December 21, 1942.

When a portion of the meniscus is missing, as in this case, there is always a dislocation of the torn fragments.

CASE 1928. The patient, aged twenty-four, was admitted July 10, 1942, with a complaint of occasional slipping, catching, and swelling in the right knee, particularly after hiking. This knee was first injured in football in 1933, and examination disclosed pain, tenderness, and clicking in the anteromedial joint space, with a slight amount of fluid in the joint. The pneumarthrograms of the lateral view (Fig. 15) disclosed a markedly enlarged fat pad with a dense fibrotic tip. At operation the anterior cornu of the medial meniscus was torn loose from its attachment to the tibia, and the thickened fat pad with a hyalinized tip overhung this portion of the medial meniscus. The anterior cornu and the fat pad were excised on July 17, 1942. The patient was returned to limited duty on December 22, 1942, with added diagnoses of essential hypertension and moderately severe varicose veins.

CASE 770. The soldier, aged twenty-three, was admitted May 25, 1942, with a complaint of stiff knee and multiple bomb fragments sustained in a raid in February 1942. On admission there were multiple scars over the anterior and medial aspects of the knee, with a wide draining area just proximal and medial to the patella. On July 24, 1942, many bomb fragments were removed with areas of dense scar tissue, and the large scar was covered with a flap of skin. On January 13, 1943, other palpable fragments of foreign bodies were removed. On February 16, 1943, a partial arthroplasty of the knee was performed with excision of the patella. Many fibrous bands and adhesions were found throughout the joint. The quadriceps tendon was lengthened and the anterior joint was lined with a fascia lata graft. The patient obtained range of motion of almost 90 degrees, and was returned to the United States on April 12, 1943.

This case is presented to show the effect of foreign bodies and chronic infection in the joint space. We have found diminished joint capacity in all cases of infectious arthritis or synovitis.

CASE 5364. The patient, aged twenty-four, was admitted February 4, 1943, complaining of inability to march, due to recurrent pain and swelling in the right knee, which was first injured in football in 1938. He showed a slight amount of increased fluid, and tenderness over the lateral joint space. The

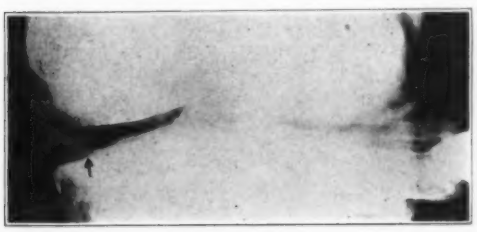

FIG. 13

Case 5602. Bucket-handle fracture-dislocation of medial meniscus. With spread of the medial joint space, note that the medial meniscus is only partially visualized. A portion of the tip and tibial surface of the meniscus is displaced into the center of the joint, leaving the small irregular fringe of the medial meniscus attached to the base. Where a part of the meniscus is found to be missing or blunted, one can always expect a dislocation of that portion of the meniscus.

FIG. 14

Case 2922. Bucket-handle fracture-dislocation of medial meniscus. With spread of the medial joint space, note the missing portion of the medial meniscus and the irregular area of the base remaining attached. At operation there was a bucket-handle fracture-dislocation involving about half of the width of the meniscus. Pneumarthrograms following surgical removal of a meniscus often have this appearance. Compare with the normal in Fig. 8-A.

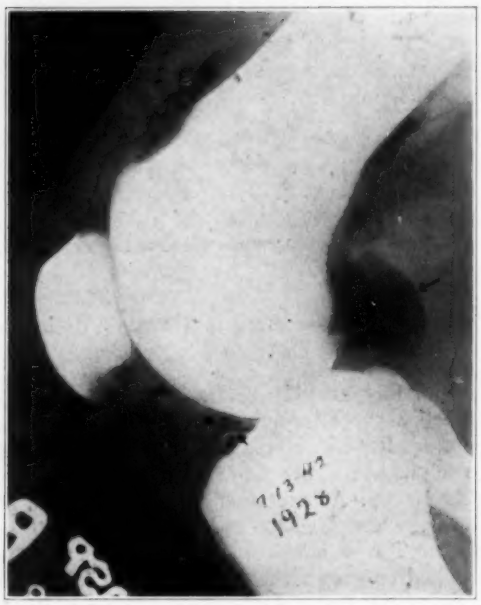

FIG. 15

Case 1928. Hypertrophied fat pad with fibrous tip. This lateral view shows greatly diminished oxygen in the anterior joint space between the patella and tibia, due to the hypertrophied infrapatellar fat pad. The fibrotic tip of the lower edge of the fat pad is clearly visualized.

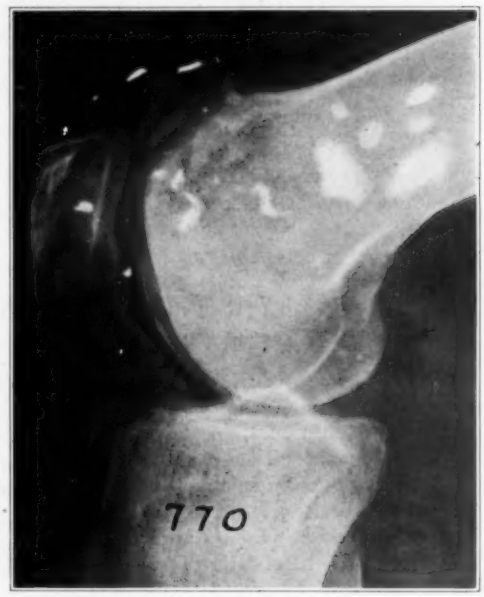

FIG. 16

Case 770. Diminished joint space, due to infection and foreign-body reaction in and around the knee joint. This lateral pneumarthrogram, made five months following injury sustained in a bombing raid, shows the marked diminution of the joint space which held only fifteen cubic centimeters of oxygen. At operation marked fibrosis and partial fibrous ankylosis, particularly around the medial condyle of the femur and patella were found. Compare with Fig. 7.

pneumarthrograms confirmed the diagnosis of a torn lateral meniscus. This was excised on February 13, 1943. At operation the posterior cornu was found to be folded back on itself, though this is not shown in the pneumarthrograms (Fig. 17). The patient was returned to duty on April 6, 1943.

CASE 5031. The soldier, aged twenty-two, was admitted on January 13, 1943, with a complaint of pain, swelling, and occasional clicking in the right knee, following an injury sustained when he jumped off a moving truck three weeks before. Pneumarthrograms (Fig. 18) confirmed the diagnosis of a torn lateral meniscus, which was removed on February 1, 1943. The patient was returned to duty on April 15, 1943.

FIG. 17

Case 5364. Longitudinal and posterior tear of the lateral meniscus. With spread of the lateral joint space, note the irregular longitudinal tear on the inferior or tibial surface of the lateral meniscus. Compare with the normal lateral (Fig. 9-A). Some of these tears may be missed at operation if only the superior femoral surface of the meniscus is inspected.

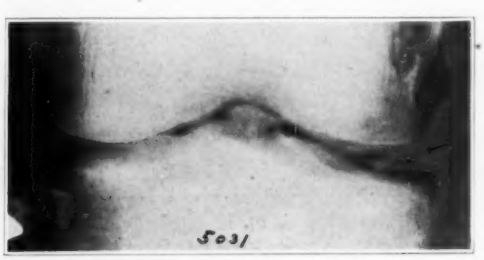

FIG. 18

Case 5031. Longitudinal tear of the lateral meniscus. With spread of the lateral joint space, note the irregular longitudinal tear through the center of the lateral meniscus, which extends almost to its base. At operation, this tear was found and the meniscus was removed. Compare with the normal lateral (Fig. 9-A).

If pneumarthrograms had not been taken, this early case would have been treated conservatively until the patient had had recurrent episodes. The clinical diagnosis was sprain with possible tear of the lateral meniscus.

CASE 1661. The patient, aged twenty-eight, was admitted June 30, 1942, complaining of pain, aching, and swelling of the left knee, and inability to march and hike. There was no recent history of injury in this case, although the patient thought he had been struck by a baseball in infancy. Examination disclosed a tender swollen mass on the lateral aspect of the knee joint. A clinical diagnosis of a cyst of the lateral meniscus was made. A plain roentgenogram (Fig. 19-A) was reported negative, although after clinical examination a spread of the lateral joint space could be seen. The pneumarthrograms (Fig. 19-B) in this case show the interesting contrast between the ordinary film and the pneumarthrograms, which show a normal medial meniscus and on the lateral side a huge meniscus, which

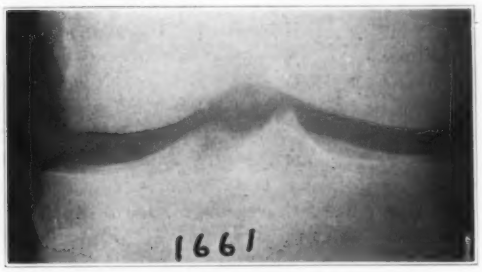

FIG. 19-A

Case 1661. Plain roentgenogram. This film was reported negative. However, soft-tissue bulging and widening of the lateral joint space can be detected on careful study. We are presenting this film to show the marked absence of detail of intra-articular structure from that obtained in the pneumarthrogram.

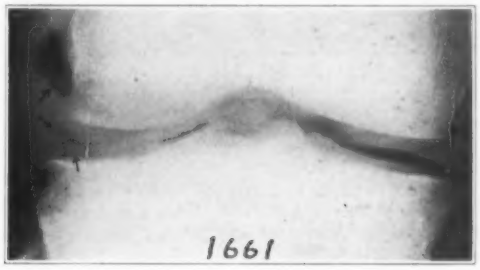

FIG. 19-B

Cyst of the lateral meniscus. When compared with the ordinary roentgenogram, it can now be seen that the lateral meniscus almost completely fills the lateral joint space, and displaces the joint capsule laterally. Note the extremely broad base of the meniscus bulging into the synovial cavity, both above and below, and the areas of decreased density in the meniscus, representing the multilocular cyst. The shadow of the medial meniscus appears normal. Compare with the normal (Figs. 6 and 9-A).

FIG. 20-A

Case 1450. Synovioma in suprapatellar pouch. This lateral view discloses the size, shape, position, and attachment of the synovial tumor in the suprapatellar pouch. This tumor is not visualized in the ordinary roentgenogram. Note the increased density of the fat pad in this pneumarthrogram. This may represent thickened synovia due to recurrent synovitis with effusion.

FIG. 20-B

This anterior view shows the rounded solid tumor, well encapsulated, situated just proximal to the patella in the suprapatellar pouch.

almost completely fills the joint space and bulges into the synovial pouch both above and below its base. The areas of decreased density in the meniscus, representing the multilocular cyst, are also visible.

CASE 1450. The soldier, aged twenty-one, was admitted September 3, 1943, with a complaint of recurrent swelling in the right knee which had begun about three years before without trauma. Examination disclosed increased fluid in the joint and a palpable mass in the suprapatellar pouch, which was attached to the floor of the bursa. The lateral and anteroposterior pneumarthrograms (Figs. 20-A and 20-B) outlined this tumor mass which did not show on the ordinary roentgenograms. A benign synovioma, which was pedunculated and well encapsulated, was excised on September 17, 1943. On November 5, 1943, the patient was returned to duty.

FIG. 21

Case 2309. Osteochondritis dissecans. Note how well the oxygen outlines the semi-detached fragment of bone and cartilage in the medial condyle of the femur. In the plain anteroposterior roentgenogram, this defect can be detected on close inspection. There is too much fluid in this knee to allow proper visualization of the menisci.

CASE 2309. The patient, aged twenty-three, was admitted July 22, 1942, with a complaint of pain, swelling, and grating in the left knee. The soldier stated that his knee was first injured when he fell from a bicycle in 1935. Examination disclosed increased fluid with medial-joint tenderness and occasional crepitus. The pneumarthrograms (Fig. 21) clearly showed osteochondritis dissecans, and the semi-detached portion was excised on July 28, 1942. This defect showed on the ordinary roentgenograms, particularly on the lateral view, but could have been missed on the anteroposterior view. The patient was returned to duty on December 23, 1942.

Fractures of the patella can also be well visualized on the anteroposterior view with pneumo-arthrography.

SUMMARY

1. A satisfactory procedure for oxygen pneumo-arthrography is presented which has been used in 508 examinations of the knee.

2. The four steps in the procedure are outlined.

3. The complicated anatomy of the lateral meniscus is emphasized and demonstrated by Figures 4 and 5.

4. The difficult interpretation of the various shadows involving the lateral meniscus is discussed.

5. A general outline for interpretation of pneumo-arthrographic findings is presented.

6. Fourteen cases in which operations were performed are described to show a variety of lesions in which the pneumarthrograms have been of value.

7. A plea is made for the necessity of perfect technique in this procedure to prevent disappointing results.

CONCLUSIONS

1. Pneumarthrograms have been made of 508 knees with only negligible local reactions and no serious complications.

2. The roentgenographic diagnosis of many internal derangements of the knee may be possible in the following types:

a. Many lesions and anomalies of the medial and lateral menisci;

b. Cysts of the popliteal space which communicate with the knee joint;

c. A few lesions of the infrapatellar fat pad;

d. Some soft-tissue tumors of the synovial membrane;

e. Some large loose bodies;

f. Relaxation of the collateral ligaments.

3. The procedure described has in many cases facilitated an early and complete diagnosis, which has hastened appropriate therapy and a quicker return to active duty.

4. Oxygen pneumo-arthrography has materially assisted the Army in the proper disposition of cases.

We wish to express our indebtedness to the many who have made this study possible, and in particular to the following:

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LATERAL DISLOCATION OF THE PATELLA

Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon

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Persistent or recurrent lateral dislocation of the patella may be either congenital or acquired. The congenital variety includes dislocations resulting from relaxation of the soft tissues about the joint (Fig. 1), from the flat or sloping anterior surface of the lateral femoral condyle, from an occasional congenital knock-knee (Fig. 2), or from the rare instances of maldevelopment of the extensor mechanism of the knee. In this latter type, the quadriceps femoris muscle itself may be present, but atrophied and weak from disuse. The patella may be abnormally placed in the quadriceps tendon or displaced far to the side, and the patellar tendon may be inserted on the lateral aspect of the tibia. In some instances, there appears to be complete absence of the vastus medialis portion of the quadriceps femoris muscle.

The acquired type of dislocation may result from one or more traumatic dislocations in which there is a tear and subsequent faulty repair of the soft-tissue structures on the medial aspect of the knee, or from an acquired knock-knee deformity. Frequently dislocation is produced by the abnormal pull of a biceps femoris tendon which had been previously transplanted to the patella in an attempt to replace a paralyzed quadriceps muscle in poliomyelitis. Several years ago, transplantation into the patella of the biceps femoris tendon alone was a commonly practised procedure in attempting to provide a substitute for a paralyzed quadriceps mechanism. Adequate follow-up over a period of several years revealed that many of these patients developed a lateral subluxation of the patella from

Fig. 1

Mother with unilateral congenital dislocation of the patella, and two children, aged six years and four years, with bilateral dislocations of similar type. These were due apparently to congenital relaxation of soft-tissue structures on the medial aspect of the joint. The two children, although operated upon, are not included in this report because of insufficient time elapsed since the operation.

the unbalanced pull of the transplanted tendon. This was the factor primarily responsible for the institution of the double hamstring transplant,—namely, simultaneous transplantation of the biceps femoris and the semitendinosus tendons in order to produce a balanced pull on the patella from both the medial and lateral aspects.

Many operative procedures, sixty according to one report, have been described for correction of persistent dislocation of the patella. These have been adequately reviewed by Campbell and by Hauser so that repetition seems unnecessary here. Likewise, no attempt will be made to discuss the merits of the various procedures. Each will undoubtedly give satisfactory results in many instances, but none can be fully depended upon to afford permanent satisfactory correction in all cases.

In this series of forty-three dislocating patellae, most of which have received treatment at the St. Louis Unit of the Shriners' Hospitals for Crippled Children, thirty are classified as congenital in origin, and thirteen as acquired. Of the thirty congenital cases, twenty-five have been thought to result primarily from congenital relaxation of the soft tissues about the joint, four from a marked congenital knock-knee deformity, and one from maldevelopment of the quadriceps mechanism. Of the acquired type, eleven resulted from the transplantation of the biceps femoris tendon into the patella in an effort to replace a paralyzed muscle after an attack of poliomyelitis; one was thought to be due to repeated traumatic dislocations, and one resulted from an acquired knock-knee deformity.

FIG. 2

Bilateral congenital dislocation of the patella, associated with or resulting from marked congenital knock-knee.

Four different operative procedures have been used in the treatment of these forty-three knees. In the few instances where knock-knee deformities were present, osteotomies and realignment of the extremity were performed in addition to other reconstructive procedures. Osteotomies, therefore, are not included in the following consideration. In one series of four knees, the lateral half of the patellar tendon was transplanted to the inner surface of the tibia according to the method of Goldthwait. Recurrent dislocations occurred in two of these knees during the first year after operation, and the results were classed as unsatisfactory. From a second series of five knees, in which the semitendinosus tendon was transplanted into the patella, four were satisfactory, while in one, dislocation recurred very soon after operation.

In a third series of eleven knees, the tibial tubercle [tuberosity of the tibia] alone was transplanted, medially and lower on the shaft of the tibia, similar to the procedure described by Hauser. This was the procedure most frequently used at the Shriners' Hospital between the years 1931 and 1935. Of the eleven cases, nine remained satisfactory, and recurrent dislocations followed in two of the knees within a short period of time. This represents a failure in 18 per cent. of the cases, not greatly different from the 10 per cent. of failures for the same procedure reported by Houkom. In one of our failures, the tibial tubercle was retransplanted at a second operation, but again the dislocation recurred; this was a case of poliomyelitis in which the dislocation was due to the pull of a transplanted biceps femoris tendon. The second failure, however, was in a case of congenital relaxa-

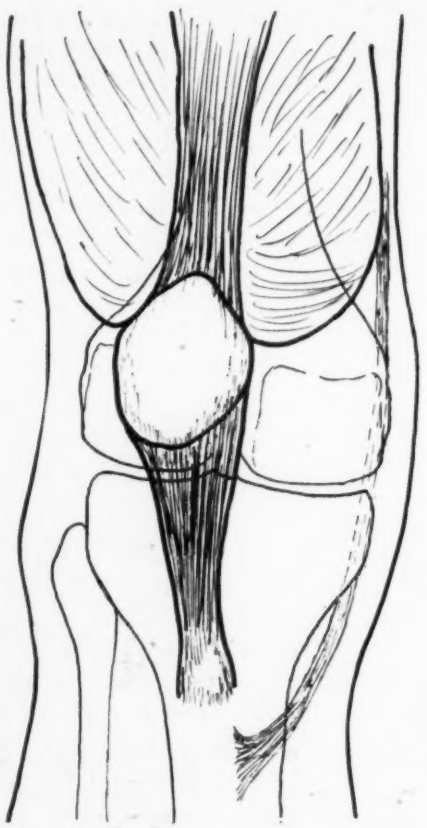

FIG. 3-A

Diagrammatic sketch of the knee, showing the usual relationships of the patella, patellar tendon, and tibial tubercle, with the knee extended in a congenital recurrent dislocation of the patella. Note that the patella lies over the lateral condyle, rather than in the groove between the two condyles. Also shown is the normal insertion for the tendon of the semitendinosus muscle.

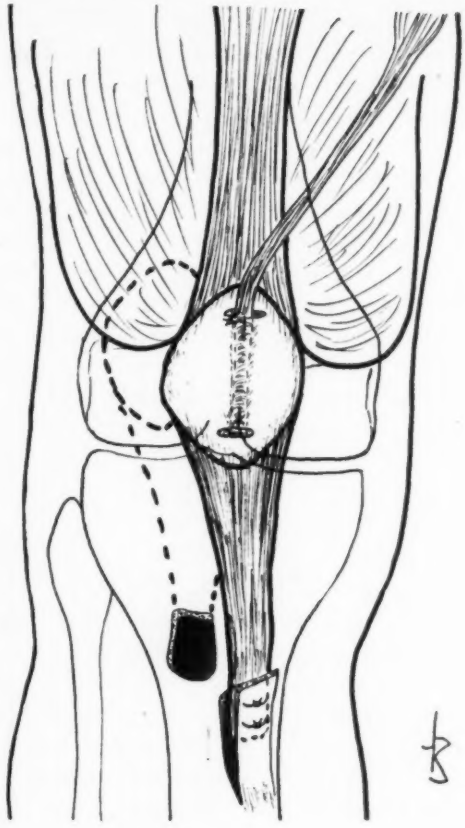

FIG. 3-B

Diagrammatic sketch, showing the same knee seen in Fig. 3-A, following operation. The tibial tubercle has been transplanted medially and inferiorly on the shaft of the tibia, and the insertion of the semitendinosus tendon has been transplanted into the patella. Note that the patella is now fixed in its normal mid-line resting position.

tion. Knock-knee deformity was not a factor in either case. The two failures for this operation in a series of eleven cases represent a percentage of unsatisfactory results too high to justify classification of the procedure as entirely satisfactory and acceptable. Transplantation of the tibial tubercle alone, therefore, has not been in use in this clinic since 1935. It has been supplanted by transplantation of the semitendinosus tendon into the patella at the same time that the tibial tubercle is transplanted. This procedure has been carried out in the remaining twenty-three knees. This is not claimed as an original procedure, because it is essentially a combination of the procedures of Hauser and Robertson, although the semitendinosus tendon is given a bony insertion into the patella. It is merely described as a relatively simple operation which has proved to be generally satisfactory. Once the patella has been shifted medially and firmly anchored to the medial aspect of the extremity from both above and below, it cannot redislocate into a lateral position. Since the procedure is usually extra-articular, there is a minimum of joint reaction and a maximum preservation of joint function.

OPERATIVE TECHNIQUE

A longitudinal mid-line incision is begun two inches (five centimeters) above the patella, and continued distally to the tibial tubercle. It is then curved medially and con-

tinued downward and medially beneath the medial tibial condyle for approximately two more inches. The skin flaps are reflected, and the broad expansion of the sartorius tendon is identified and opened in the line of its fibers. This exposes the insertions of the gracilis and semitendinosus tendons, the latter occupying the inferior position. The semitendinosus tendon is divided near its insertion, then freed from its other attachments to the adjacent tendons and ligamentous structures along the posteromedial aspect of the knee. A second incision, two inches in length, is made along the posteromedial surface of the thigh at about its mid-point. This point is made accessible by flexing the hip and knee, and permitting the hip to roll outward. By placing tension on the detached tendon below, the belly of the semitendinosus muscle can be easily felt and identified, lying along the posterior surface of the semimembranosus muscle. The overlying fascia is opened longitudinally, and the muscle belly is lifted out with the index finger. By traction, the tendon can then be pulled upward and brought out through this small incision. A larger incision is not necessary. A wider exposure only increases the amount of surrounding scar tissue, which may interfere with the gliding motion of the transplanted muscle and tendon.

By blunt dissection with scissors and a Kelly clamp, a tunnel is then made from the small upper incision, downward and forward through the subcutaneous tissue, to the upper limit of the original anterior incision. The tunnel is enlarged as needed at the proximal end in order to accommodate the muscle belly. The tendon is drawn through the tunnel and the small incision is closed.

The tibial tubercle is then detached. This can be done by placing a sharp thin osteotome directly back of the tendon, holding it parallel to the long axis of the leg, and removing only the superficial portion of the tubercle with the tendinous attachment. If the operation is being done in a growing child, which is frequently the case, care must be taken not to damage the underlying epiphyseal line of the tibia. Experience has shown that this procedure can be carried out without injury to the growth structure. A block of bone is never removed, and it is not necessary for the success of the procedure. The patellar tendon is then freed from the underlying fat pad, and the lateral fascia is opened from below upward, along the lateral margin of the vastus lateralis, sufficiently high to permit shifting the patella

FIG. 4-A

FIG. 4-B

Fig 4-A: Case 2. Congenital dislocation of the patella resulting from relaxation of the soft-tissue structures about the joint. Note the ease with which the patella can be dislocated laterally from slight pressure exerted on the medial side.

Fig. 4-B: Same knee following simultaneous transplantation of tibial tubercle and semitendinosus tendon. Note the new position for the tibial tubercle and the line of the semitendinosus tendon entering the patella. Note also the fixed mid-line position of the patella, even when marked pressure is exerted on its medial side.

to its normal mid-line resting position. By traction on the patellar tendon, the detached tibial tubercle is shifted medially and distally on the shaft of the tibia as far as possible, which is usually one to one and a half inches below its original attachment. This point is marked and, since it lies over the broad tendinous insertion of the sartorius, the structure is opened further to expose the periosteum. Then the periosteum is outlined above and on the two sides with a scalpel, corresponding to the area where the transplant will be made. With a sharp osteotome a thick osteoperiosteal flap is reflected from above downward, with the base of elevated bone and periosteum below remaining intact. Small drill holes are made in this flap, through which the tibial tubercle is firmly anchored by means of heavy suture material. The sutures are placed through the patellar tendon and tibial tubercle at a point where firm tension will be maintained on the extensor mechanism to hold the patella in its normal position (Fig. 3-B). The patellar tendon is further anchored to the adjacent periosteum, and to the overlying sartorius tendon as it is resutured. If there is any doubt about the firm anchorage of the tibial tubercle at this point, a small screw or threaded wire should be drilled through the osteoperiosteal flap and tibial tubercle into the shaft of the tibia, although this is usually unnecessary.

Next, the tunnel is prepared through the body of the patella with a small osteotome. This is prepared from above downward so that the attachment of the tibial tubercle will not be disturbed, or the tunnel in the patella can be made before the attachment below is made. The semitendinosus tendon is then passed through this tunnel. It is firmly anchored to both the quadriceps tendon and the patellar tendon, where it is buried in grooves prepared in these two structures along the course of the transplanted tendon. Moderate tension is maintained on the transplanted tendon while the initial sutures are placed.

FIG. 5-A

Case 3. Recurrent dislocation of right patella, due to mild congenital relaxation and superimposed trauma. Correction by simultaneous transplantation of tibial tubercle and semitendinosus tendon at eighteen years of age. Photograph shows appearance of scar after seven years. Note the similarity of contour of the two knees.

FIG. 5-B

Note the degree of flexion which is possible seven years following operation.

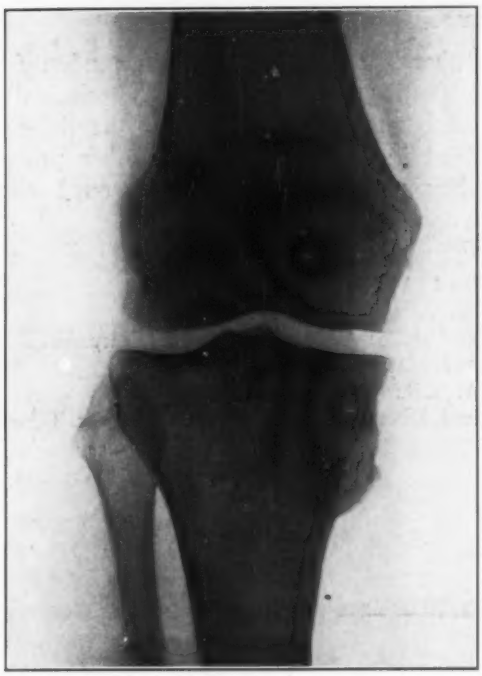

FIG. 5-C

Roentgenogram showing anteroposterior view of knee seven years following simultaneous transplantation of tibial tubercle and semitendinosus tendon. Note the mid-line position of the patella and the excess bone formation on medial aspect of tibia, marking the point of new attachment for the tibial tubercle. The knee joint itself retains its normal contour.

FIG. 5-D

Roentgenogram showing lateral view of same knee seven years after operation. Note the concavity on the anterior surface of the tibia where the tibial tubercle was detached. This was an adult knee and some bone was transplanted with the tendon. Note also the tunnel along the anterior surface of the patella, which marks the new insertion of the semitendinosus tendon. The smooth articular surface of the patella is not disturbed.

No attempt is made to close the opening in the lateral fascia. Closure is carried out in the usual way, and the extremity is encased in a plaster cast, extending from the toes to the groin. Sutures are removed after one week, but the cast is continued for four weeks. If postoperative swelling has necessitated cutting the original cast, a new one is applied when the sutures are removed. After four weeks, a skin-tight plaster cuff is applied, which extends from the upper thigh to within two inches of the malleoli. This is applied over stockinette which is anchored to the leg by skin application of an adherent. The knee is held in flexion of about 5 degrees, in order that it may be more comfortable. Weight-bearing, without crutches, is then instituted, and the patient is permitted activity. The plaster cuff is removed after another four weeks (making a total of eight weeks of immobilization), and the patient is permitted to re-establish motion in the joint by active use.

RESULTS

This procedure has been performed on twenty-three knees, twenty in children under sixteen years of age, and three in adults. Satisfactory function has been restored in all the joints, and no recurrent dislocations have followed. Cases which have not been followed for at least one year after operation are not included. The longest follow-up has been seven years, and the average is three years.

Essentially normal motion has been established in all joints. A moderate amount of traumatic arthritis was present in two of the adult knees prior to operation, presumably due to the recurring dislocations. There was definite improvement in the amount of crepitus felt on motion after operation.

SUMMARY

Simultaneous transplantation of the tibial tubercle and semitendinosus tendon for correction of lateral dislocation of the patella is a rational procedure, and not technically difficult. In twenty-three consecutive cases, there has been no recurrence of the dislocation, and satisfactory function has been maintained in all cases. Various other procedures, previously described, have failed to give the same satisfactory results in our hands.

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DELAYED PRIMARY CLOSURE OF WOUNDS WITH COMPOUND FRACTURES *

BY LIEUTENANT COLONEL MATHER CLEVELAND AND MAJOR JOHN A. GROVE

Medical Corps, Army of the United States

The initial treatment of the wounded soldier with a fracture, due to gunshot, shell, mine, or other external explosive force, consists of a careful débridement, or surgical excision of devitalized tissue. This tissue is largely muscle, the fibers of which have been killed by the enormous expansile force of the high-velocity projectile. Fascial planes are opened widely to relieve all tension. Every effort is made to conserve skin and bone, since an intact skin is essential to healing of all underlying structures, and an intact bone is essential to the proper support of the involved part. Easily accessible foreign bodies and bits of clothing are removed. A vaseline-gauze dressing is lightly inserted to the depths of the wound. This dressing is merely intended to keep the skin edges from immediately falling together, and thereby blocking drainage, should infection supervene. It is not intended, and should not be used to "pack" the wound open. The extremity is then encased in a circular plaster-of-Paris dressing to allow as comfortable transportation as possible. The forward hospitals are not held responsible for the anatomical reduction of these fractures.

The time elapsing between receiving a wound and arrival in a General Hospital, where definitive treatment of compound fractures may be instituted, has increased as the battle front has moved forward farther and farther beyond the Normandy beachhead. During the summer months following D-Day, our wounded arrived in the United Kingdom three to five days after being wounded. At the present time, the average interval is ten days to two weeks and, in some instances, much longer.

When the battle casualties with compound fractures arrive at these General Hospi-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

tals, the plaster-of-Paris and vaseline dressing are removed as soon as possible, and the underlying wound and fracture are inspected. If conditions are satisfactory, skeletal traction is applied to secure proper length and alignment of the fracture.

Skeletal traction is maintained by a Kirschner wire or Steinmann pin, with the extremity in balanced suspension in an army ring splint, with a Pearson attachment for long-bone fractures of the lower extremity. The ring splint is very rarely used for upper-extremity skeletal traction. Skeletal traction secures and maintains reduction of the vast majority of these fractures of the long bones. It is continued until the fractures have consolidated or "frozen" sufficiently to ensure maintenance of position in circular plaster-of-Paris dressings, during the period of transfer to the Zone of the Interior. While these fractures are in skeletal traction, exercise of involved muscles is encouraged to secure motion in the joints above and below the fracture site. This holding period for these compound fractures varies from five to ten weeks, depending upon the site and type of the fracture. During this time every effort is made to convert the fractures from a compound to a simple state by closure of the wounds by suture or skin graft, or by employing plastic procedures, where there has been such extensive loss of skin that there is no possibility of restoring an intact integument with the tissue remaining. We have seen a great many of these wounds that can be immediately closed by suture at the time of the first dressing.

The technique of closure of these wounds should be considered at the earliest possible moment. The skin edges during the first ten days are mobile, and usually they may be readily approximated, if there is little loss of skin. A careful, minimal, secondary débridement may sometimes be required; but wet dressings of saline solution, applied for a day or two, will usually clear away the surface debris. The wound should be approximated with widely spaced and deeply placed non-absorbable sutures, without tension. If a skin graft is required, the recipient site is almost invariably treated with the wet dressing already mentioned, for approximately three days prior to operation. Delayed closure of wounds, where more than ten days to two weeks have elapsed from the time of wounding, requires removal of the new epithelium and mobilization of the skin by gentle undercutting of the edges which have become adherent. Hemostasis must be secured in any event. In either early or delayed closure, a small, rubber tissue drain is often left in the wound for twenty-four to forty-eight hours.

No attempt is made to secure a cosmetic result in these extremity wounds.

The advantages which accrue from the successful closure of these wounds are obvious. Underlying exposed bone is conserved, and healing of bone and soft tissue is accelerated. The prolonged drainage incident to healing of the wound from the depths to the surface by scar tissue is obviated. Repair of divided peripheral nerves, open reduction of such few fractures as require this procedure—with bone grafts where necessary—all may be accomplished relatively early and with greater ease.

While it is too early to state conclusively the final outcome of this type of surgery, certain facts may be presented and trends noted from statistical data, collected at several of our medical installations.

Major John Grove has collected a large series of cases from the hospital center of which he is Surgical Coordinator. Lieutenant Colonel John C. Eckells, and Lieutenant Colonel Elliott Thieme have contributed series of cases from the respective hospitals where each has been serving as Chief of Surgical Service. Major James Barr has made a very detailed study of the closure of wounds in cases of compound fractures on his Service. An attempt to briefly summarize these various observations will be made.

1. *A Study of Ninety-Seven Compound Fractures of Long Bones in Prisoners of War*

In many instances these prisoners were caught between the lines of fire and considerable delay resulted between the time of receiving the wound and the first definitive treatment. Only sixteen of these ninety-seven patients had received penicillin or other

chemotherapy prior to débridement. Only thirty-three of these ninety-seven wounds, or 34 per cent., were considered clean enough to be closed by delayed suture.

2. *A Study of Closure by Suture of the Wounds of Fifty-One Prisoners of War*

There was complete success in thirty-two cases, or 62 per cent.; partial success in fifteen, or 29 per cent.; and complete failure in four, or approximately 8 per cent.

An effort to reach any conclusions in this small series of patients yields the following:

a. *The Effect of Penicillin on Eventual Healing of the Sutured Wound*

Only seven of these fifty-one patients received any penicillin, an average of 50,000 units each, before primary surgical débridement was done; while thirty-one patients received approximately 120,000 units each, following débridement.

Of the four complete failures, two received penicillin and two did not.

b. *Time Elapsed Between Wounding and Primary Surgical Débridement in Relation to Successful Closure of Wound*

The thirty-two patients whose wounds healed promptly and completely by delayed suture included three whose primary débridement was done on the day of wounding, while the average time elapsed for the remaining twenty-nine was thirty-two hours.

Of the nineteen patients in whom closure was a complete or partial failure, débridement was done on the day of wounding in six, and in the remaining thirteen after an average of seventy-two hours.

This evidence simply furnishes corroboration of the established fact that delay between wounding and débridement favors a higher incidence of infection—often serious, as in the case of these prisoners, where gas bacillus gangrene and tetanus resulted.

3. *Certain Factors Influencing Healing of Wounds Over Compound Fractures by Delayed Primary Suture*

This is a careful study of seventy-three soldiers with 107 wounds compounding their fractures. A final closure by suture of 90 per cent. or more of the wound was considered a successful outcome in this series. The results were analyzed in relation to the following six factors:

a. Status of red blood cells and hemoglobin,
b. Location of wound,
c. Size of wound,
d. Type of discharge from wound,
e. Chemotherapy,
f. Time elapsed between wounding and closure of wound.

a. *Status of Red-Blood-Cell Count and Hemoglobin Determination*

This is of great importance. In patients with a red-cell count of two to three million cells and hemoglobin of 50 to 60 per cent., the successful closures recorded were 63 per cent. and 53 per cent., respectively; while with red-cell counts of four to five million and hemoglobin determination of 80 to 90 per cent., the closures were successful in 95 per cent. and 88 per cent., respectively. The obvious explanation is that many of our wounded require adequate blood transfusion when they arrive in General Hospitals.

b. *Location of the Wound*

With good mobility of the skin and abundant subcutaneous tissue, wounds are more readily closed. Of the wounds of the shoulder, arm, forearm, and hand, selected for closure, 100 per cent. were successfully closed and remained healed, whereas only 67 per cent. of the wounds of the leg, ankle, and foot were successfully closed and remained healed. The fact that wounds of the lower extremity are more apt to be contaminated by bacteria must also be considered in part responsible for the greater number of failures of successful closure of wounds of the leg, ankle, and foot.

c. *Size of the Wound*

The chance of closing a wound by suture varies inversely with its size. Skin grafts must be used in many of the larger wounds.

d. *Type of Discharge from the Wound*

Wounds with serous discharge may be readily closed, but, if there is a seropurulent discharge from the wound, a high percentage of failures must be expected. Basic surgical principles of course cannot be violated with impunity.

e. *Chemotherapy*

In this series of wounds, the largest number of partial or complete failures were recorded in the sixty-three wounds in patients who received penicillin, sulfadiazine, or both after admission to this hospital. It is fair to assume that this group probably consisted of the least favorable wounds from all standpoints. The use of these chemotherapeutic agents is no guarantee of success in closing wounds the bacteriology of which is unknown.

f. *Time Elapsed from Wounding to Closure*

All of these wounds were closed within thirteen days or less following wounding, and it was found that wounds closed on the thirteenth day healed and remained healed as readily as those closed on the eighth or ninth day.

4. *Closure of Wounds over Compound Fractures in a Large Hospital Center*

One of the hospital centers of our medical installations in the European Theater of Operations, during the past five months, has received and treated 5,042 compound fractures, excluding the bones of the face, skull, and spine with associated spinal-cord injury. All but a few of these fractures resulted from battle casualties. The bones of the lower extremity were involved in 2,614 instances; those of the upper extremity, in 1,895; and all others, including the pelvis, scapula, patella, clavicle, and vertebrae in that order, comprised a group of 533. The bones most frequently fractured were the tibia (757), humerus (702), and femur (684). Fractures of the long bones were, for the most part, treated with skeletal traction and balanced suspension.

Delayed primary closure of the wounds of these compound fractures was attempted in 2,393 patients. The average time between wounding and closure of the wound in this series was fourteen days. Closure of the wound was accomplished by suture in 2,087 cases, by skin graft in 236, and by combination of suture and skin graft in seventy cases.

In many large wounds with frank infection, a partial closure of the wound was performed with free drainage at the site of maximum infection, and at times counterincision was made for dependent drainage. The partial closure of large draining surfaces prevents loss of serum, and is accompanied by marked improvement in the patient's general condition.

In this extensive series of cases, it was noted that anaemia was common, and transfusions of whole blood were frequently required to build up the patient's general condition.

Elevation of the wounded extremity, and skeletal traction with balanced suspension reduced the oedema of the part, and facilitated closure of the wound.

Skin-grafting by split-thickness free grafts has been done with increasing frequency; and in wounds with considerable loss of bone and soft tissue, especially those of the hands, feet, and forearms, pedicle grafts are being employed. These pedicle grafts are performed at those hospitals designated for plastic surgery.

Results of Surgical Closure: The results of the attempts to convert these compound fractures into simple fractures were as follows:

a. *Complete success* with healing by primary intention occurred in 1,592 cases, or 66.53 per cent. of the total.

b. *Partial failure* occurred in 640 cases, or 26.74 per cent. of the total.

Those cases rated as partial failures showed a small sinus, a stitch abscess, or a par-

tial loss of a skin graft. All but a very few of these wounds, counted as partial failures, healed by a second suture or skin graft or spontaneously, and were healed when the patients left the hospital. This means that a total of 93 per cent. of the patients in whom closures were attempted left the hospital with their wounds healed.

c. *Complete failure* occurred in 161 cases or 6.73 per cent. of the total.

By complete failure is meant an entire breaking open of the wound spontaneously, or the development of an osteomyelitis which necessitated the wide opening of the wound surgically.

Common sites for these complete failures were wounds involving the upper third of the femur, or the pelvis, complicated by penetration of bladder or bowel. The wounds involving the lower third of the leg and foot also ranked high among the complete failures. Cultures of bacteria from these wounds, which failed to heal, revealed a mixed type of infection with staphylococci and bacilli of the colon group predominating.

Spontaneous Healing of Compound Fractures: It is interesting to note that among these 5,042 compound fractures, 2,152 cases, or approximately 42 per cent. of the total, showed spontaneous healing of the wounds during the period the patients were hospitalized in this theater of operations. The majority of these were small penetrating or perforating wounds.

Healing of the Wounds of the Entire 5,042 Compound Fractures: In this series of patients, failure of healing was noted in 161 unsuccessful attempts at closure, and in 497 of the 2,649 patients on whom no attempt at surgical closure was made,—a total of 658 wounds which failed to heal in the entire 5,042 cases. The maximum holding period for these patients in this theater of operations is approximately ten to twelve weeks, depending upon the fracture. It is significant that within this time, 87 per cent. of these fractures were converted from compound to simple state by healing of the wounds.

Osteomyelitis: Frank infection of the fractured bone was noted in 272 patients, an incidence of 5.4 per cent. of the total.

SUMMARY

Delayed primary closure of wounds over compound fractures can be accomplished by surgical means in a very high percentage of battle casualties. In a series of 2,393 closures of wounds over compound fractures, 93 per cent. had healed when the patients left the hospital.

The factors which seem to influence the success of this treatment are:

(1) *Early and adequate surgical débridement* of the wound.

(2) *Rapid evacuation* of the wounded to the rear medical installations, where this definitive treatment may be carried out.

(3) *A low incidence of serious infection,* which is due to the early surgical treatment mentioned above, and to the age and generally excellent physical condition of the patients involved. The use of sulfonamides and penicillin probably exerts a beneficial influence on this low incidence of infection. Controlled experimental proof of this is not available.

(4) *Whole-blood transfusions* to combat the anaemia, which is present in many of these wounded, ensure a higher percentage of successful surgical closures of wounds.

EXPERIENCE WITH WHOLE BLOOD AND PLASMA *

BY CAPTAIN FOREST H. COULSON

Medical Corps, Army of the United States

In the preinvasion planning for the use of whole blood in casualties among the United States Forces, estimates were made that plasma would be sufficient to restore blood volume in nine wounded out of ten. The tenth man would need a blood transfusion and, even in his case, plasma would be used in the ratio of two units for one of whole blood.

The European-Theater-of-Operations Blood Bank was established to supply units of Type O whole blood to Clearing Stations, Field Hospitals, and Evacuation Hospitals in the Army Area, and to Station and General Hospitals in the Communications Zone. It was felt that these units would be unable to supply whole blood in sufficient quantities for their needs, or to practise a technique suitable for the preparation of intravenous fluids under field conditions.

Whole blood has been shipped by air transport almost daily since June 13, 1944, from the Blood Bank to Blood Bank Detachments in France. During the first week of the invasion it was carried to the beaches on LST's (Landing Ship Tanks) and Hospital Carriers. The units of blood were packed for the journey in Quartermaster refrigerator cans with ice as the refrigerant. Delivery to medical units was made by detachments of the Blood Bank, equipped with refrigerators on trucks.

Within the first month after D-Day, it became apparent that the E. T. O. Blood Bank alone could not furnish all of the Type O blood, demanded by medical units in France. A call was made to the United States for a daily supply of whole blood to supplement that produced in the United Kingdom. There had been no lull in the activities of the American Red Cross in the United States in securing blood from civilians for the supply of plasma. Under the direction of the Surgeon General, part of the blood collected in Washington, New York, and Boston was used to help meet the unexpected demand. As a preservative, 500 cubic centimeters of Alsever's solution was used, when the blood was not refrigerated during the flight to the United Kingdom. It was determined that in this solution there was not sufficient hemolysis of red cells to be dangerous to the recipient.

On August 24, the first shipment of blood from the United States landed at an airport in Scotland, and daily shipments were received there until the planes from the United States could land directly in Paris. After twenty-four hours of refrigeration, supervised by a Blood Bank Detachment, the blood was flown from Scotland to France, where it was combined with shipments from the E. T. O. Blood Bank, and distributed to the medical units.

A third source of whole blood has appeared with the establishment of the second E. T. O. Blood Bank, which has been operating in Paris since November 1.

There are three main reasons for the use of blood, far in excess of expectations. First, when there has been a rapid and copious loss of blood, plasma alone has been found insufficient. This condition is an indication for immediate transfusions of whole blood, and as many as four or five units have been given to these patients over a period of a few hours. Only in casualties with relatively small loss of blood or slow hemorrhage can plasma be used to restore part or all of the blood volume. Second, emergency surgical procedures requiring the support of whole blood, preoperatively and postoperatively, are being done more frequently and farther forward in the line of evacuation than was expected. A third cause of the great demand is the fact that whole blood has become so readily available through the Blood Bank. Furthermore, it is so easy to use, when typing and crossmatch-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

ing are not necessary, that it is being used to support patients with gas gangrene and other severe infections during their course of therapy with sulfadiazine and penicillin.

Accurate figures, showing the actual comparison in the use of plasma and whole blood for war casualties, are not yet available; but certainly the ratio will not be that expected before D-Day.

TRANSPORTATION OF THE WOUNDED SOLDIER *

BY LIEUTENANT COLONEL JOHN G. MANNING
Medical Corps, Army of the United States

It is the policy of the Medical Corps of the United States Army to transport the wounded soldier to the rear as rapidly as possible, and to administer definitive therapy in General Hospitals. At the present time, all patients with fractures of the long bones are transported to General Hospitals in the United Kingdom, where the fractures are reduced by skeletal traction, and delayed primary wound closures are performed to convert compound fractures into simple fractures. The long journey from the front line is made in short trips by ambulance, hospital train, and hospital ship, or by airplane. If airplane travel is not available, ten to fourteen days are usually required to move the wounded soldier from the German border to a General Hospital in the United Kingdom.

The care given to the soldier in the forward areas and during transit is directed toward the relief of pain, prevention and treatment of shock and infection, and ensuring comfort.

From the battlefield to the Battalion Aid Station the wounded are carried either by litter bearers, or by litter-carrying jeeps. As much use as possible is made of the jeeps, to save both time and labor. Armored vehicles are sometimes used, especially if the battle is quite active. The time required to move the wounded back to the Aid Station varies considerably, depending upon weather, terrain, and battle conditions. Under favorable circumstances, however, it is possible to remove the majority of litter cases in half an hour.

At the Battalion Aid Station, the first real opportunity is afforded to apply an adequate splint for fracture of the long bones. The Army half-ring leg splint, with ankle traction strap, is put on for fractures of the thigh and leg. Velpeau's bandage is applied for fractures of the humerus, and wire ladder splints for fractures of the forearm and wrist, and ankle and foot. After the soldier's wounds have been dressed, splints applied, and morphine and sulfonamides administered, he is transported by ambulance to a col-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

lecting point, called the collecting company. This ambulance haul usually takes from ten to fifteen minutes. At this point, cases are sorted, and those soldiers requiring further first-aid treatment, application or reapplication of splints, or resuscitation are held until that treatment can be administered, while the others are transported on to the clearing company. During the month of November, the majority of cases arrived back at the clearing company within an interval of two to four hours from time of wounding. At this installation, penicillin is administered, and blood and oxygen are available for resuscitation. Here, further sorting is done, and a few men remain at this point for treatment. The patients who are able to be transported are sent by ambulance to the Evacuation Hospitals, five to twenty-five miles to the rear. The cases of abdominal and chest wounds and other patients who, in the opinion of the medical officer, will not tolerate a long ambulance ride, are sent to the Field Hospital which is set up within a few hundred yards of the clearing company. This is the farthest forward medical installation which is equipped to perform primary surgical treatment.

At the Evacuation Hospital where most of the extremity wounds receive primary surgical treatment, another sorting occurs to determine priority for surgery. Careful débridement of the wounds is performed, and the fractures are immobilized in circular plaster-of-Paris splints for transportation. These plaster splints are not intended to hold the extremity in reduction, or even in good alignment, but are for the purpose of immobilization of the bone and soft tissue, so that the soldier can be transported comfortably. Evacuation and Field Hospitals are the first medical installations in which plaster-of-Paris splints are applied. The following splints are used: circular plaster for fractures of the bones of the forearm; Velpeau's plaster bandage, and shoulder spica for fractures of the shoulder and humerus; double plaster-of-Paris spica for fractures of the femur; long circular plaster-of-Paris for fractures of the tibia and fibula; short circular plaster splints for fractures of the foot. All circular plasters applied to extremities are split down to the skin so as to divide all circular dressings. The majority of patients with fractures which do not have other complicating lesions are ready for transportation within twenty-four to thirty-six hours after débridement has been performed.

From the Field and Evacuation Hospitals the soldier is again transported by ambulance to a center which is served by hospital trains, or which has airfields located nearby. In this center there are usually a number of General Hospitals which serve as Transit Hospitals. The time required for the ambulance trip from the Evacuation Hospital to the General Hospital again varies with the distance, but is usually not more than two to three hours. At the Transit Hospitals the chemotherapy is continued, and any complication which may have arisen is dealt with. As soon as a hospital train is available for loading, the men are transported to it by ambulance. The trip by hospital train to another hospital center usually takes twenty-four hours. The patients are then held in another Transit Hospital either for air evacuation or transfer to another hospital train, which will take them to a port. This trip requires twenty-four to thirty-six hours. At the port the men are again held in a hospital for transport by air if available, or for transfer to a hospital ship. The hospital ship crossing requires twelve to twenty-four hours. The patients will again be held in a Transit Hospital until a hospital train is available. From the hospital train they are transported by ambulance to the General Hospital in the United Kingdom.

If they are transported by air, they will arrive at an airfield in the United Kingdom, pass to Transit Hospitals by ambulance, thence to hospital train, and by ambulance to the General Hospital.

The journey is a long one, but the patients have been able to tolerate it, because all along the route of evacuation they have received medical attention, and have been given good general care. Although the time required for evacuation is very long, we believe that, except in a few instances, it has not jeopardized the soldier's life or limb.

THE INTERVERTEBRAL DISC: ITS MICROSCOPIC ANATOMY AND PATHOLOGY

Part III. Pathological Changes in the Intervertebral Disc

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In previous papers * we have discussed the anatomy, development, and physiology of the intervertebral disc, and the changes in it concomitant with age. The borderline is indistinct between the degenerative changes accompanying the aging process, and those that may be termed pathological. In many instances, it is difficult to know where one ends and the other begins. While destruction of a disc by infection is definitely pathological, there are the additional changes produced by senescent arthritis or nuclear expansion. In lesser degrees both of these changes are so often encountered in certain age periods as to be considered normal. However, in their more advanced forms, they are abnormal or pathological. Usually, pathological changes are manifested in the roentgenogram of the

TABLE I
Incidence of Pathological Discs

Pathological Changes	Number of Cases
Nuclear expansion	7
Ballooning	5
Thinning	9
Intraspongy nuclear protrusions (Schmorl bodies)	
Microscopic	56
(Gross 5)	
Anterior nuclear protrusions	1
Posterior nuclear protrusions	7
Calcified nucleus pulposus	1
Invasion by infection	1
Invasion by malignancy	1
Total	88 *

* Routine necropsy specimens 85; added cases 3.

gross specimen by such phenomena as thinning, "ballooning", and calcification of the nucleus. However, microscopic changes which are not visible by roentgenogram may also be pathological.

The pathological changes to be discussed have been found in discs removed during routine necropsy, with the exception of three cases which were added to complete the study. These added specimens showed: (1) a disc invaded by carcinoma; (2) a disc destroyed by infection; and (3) a disc in the thoracic region from a case of senile osteoporosis. In considering Table I, it should be remembered that the incidence of pathological discs found in this study only approximates the actual incidence of pathological discs in the patients studied. It has been impossible to determine in how many cases there were bony spurs, for a microscopic section takes in only a very small amount of a disc and the adjacent vertebrae. The same may be said of all the other pathological affections, although a disc which has undergone definite pathological changes usually exhibits some of these changes in all of its parts. Of course, the recorded incidence of pathological specimens, in which diagnoses were made from the thinning, ballooning, nuclear expansion, calcifi-

* See Part I (p. 105, January 1945) and Part II (p. 233, April 1945).

cation, and Schmorl bodies visible in the roentgenograms, is fairly accurate, and of some significance.

A. HYPERTROPHIC ARTHRITIS

Beadle, quoting Schmorl's work, stated that the osteophytes form just below the outer edge of the epiphyseal ring on the front and sides of the vertebral bodies. They may grow to enormous size, and may fuse with the adjacent spurs from above or below. They appear to be linked by calcification in the longitudinal ligaments, often seen in spondylitis deformans.

The cause of osteophytic growth in the spinal column was first expounded by Beneke, in 1897. His theory was that because of degeneration, with resultant loss of disc substance, there is increased movability of the vertebral bodies on one another. As the motion increases, tension is placed on the attachment of the longitudinal ligament above and below the disc anteriorly. The ligaments are implanted deeply in the bone as Sharpey fibers. This pulling stimulates the periosteum to formation of new bone, much as the tension on tendinous attachments among children causes characteristic bony ridges and tubercles.

Why osteophytes do not usually occur posteriorly is also explained by this hypothesis. Since the posterior longitudinal ligament is not attached firmly to bone, tension on it tears the annulus, to which it is adherent, but does not stimulate the periosteum to any extent.

Donohue modified this hypothesis of the causation of osteophytic growths by stating that it is the lateral and anterior bulging of hypermobile, degenerated discs that stretches the ligaments and in turn pulls on the periosteum, causing it to create new bone.

B. NUCLEAR EXPANSION

The majority of the discs in the lumbosacral region, beyond the age of fifteen years or so, exhibit a varying degree of what is spoken of as nuclear expansion. For this reason

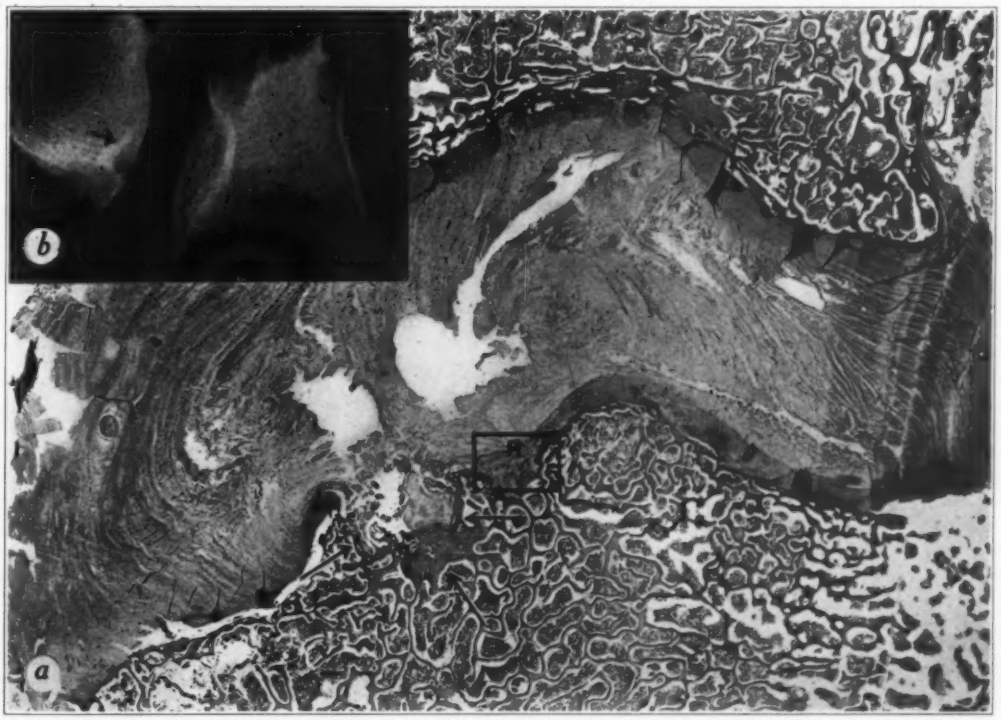

FIG. 1

Intervertebral disc of a youth, aged twenty years. *a*. Section (× 3.75), showing nuclear expansion. Arrows indicate a Schmorl body. *A* (box) is enlarged as Fig. 5 of Part II of this series of papers. *b*. Roentgenogram. The arrow indicates a Schmorl body.

one hesitates to classify nuclear expansion as a pathological entity. As the name implies, there is expansion of the disc in the region of the nucleus pulposus, at the junction of the middle and posterior thirds of the disc. This occurs most prominently in the lumbar region. This expansion is physiological rather than pathological, except in its marked degrees, in which it may truly be termed abnormal (Fig. 1,*a* and *b*). Seven cases of marked expansion—that is, expansion enough to be termed pathological—have been encountered in this study.

Nuclear expansion is due to the turgor and potential force in the nucleus pulposus. It is natural for the nucleus, under tension, to expand somewhat into the adjacent bone. This bone is not osteoporotic in the disc which shows nuclear expansion. When osteoporosis is present, ballooning takes place instead. This is a diffuse, rather than a localized, expansion. Schmorl found nuclear expansion at very early ages, and expressed the belief that it is caused by developmental defects in the cartilaginous plate. Beadle qualified this, stating that it results from slight trauma to a spinal column in which there is an unexplained congenital weakness. No one, however, has explained why expansion does not occur in discs in which there are multiple defects of the cartilaginous plates. Some of the specimens in this study have all the factors that one would think necessary for marked expansion, but none occurs. The fact that expansions occur most commonly in the young middle-age group supports Übermuth's contention that it is at this time that the nucleus functions most strongly and is at its "high-water-mark".

This study has confirmed most of Schmorl's observations on nuclear expansion,—namely, thinning of the cartilaginous plate at the point of maximal bulge (this could theoretically be a result rather than a cause of expansion), and defects in the region of the bulge, with occasional nuclear protrusions. The nucleus is in good condition,—that is, in specimens exhibiting expansion, it is not fibrotic or desiccated. Perhaps the only cause for nuclear expansion is that the nucleus itself has an abnormally high water content, with resulting increased tension. At any rate, nuclear expansion, even when it is considerable, probably does not produce clinical symptoms.

FIG. 2-A

Ballooned intervertebral disc (× 3.5) of a man, aged sixty years, suffering from osteoporosis.

C. BALLOONED DISCS ("FISH VERTEBRAE")

Ballooning of the intervertebral disc is found in osteoporosis. This is a disease of unknown origin, affecting the entire spinal column and often the pelvic bones. It usually is encountered among persons beyond middle life. It is most frequent among women following the climacteric. The clinical aspects of osteoporosis are adequately discussed by Black, Ghormley, and Camp. The bone of the vertebrae is changed so that the trabeculae of the substantia spongiosa are decreased in size and number, and replaced by bone marrow. This removes the struts that give strength to the bone, which in consequence becomes more easily collapsible than in its normal state.

FIG. 2-B
Roentgenogram of the intervertebral disc shown in Fig. 2-A.

To have ballooning of the disc, even when osteoporosis is present, one must have a fairly normal disc, one that is expansile and elastic (Schmorl). Otherwise anterior wedging and narrowing of the vertebrae may occur and the disc may remain normal in thickness. In addition, there must be certain stresses placed on the disc to mold it into the characteristic lens shape. The increase of the size of the disc is most probably due to an increase of water content and not to an actual increase of tissue.

Why does the greatest indentation occur at the center of the vertebra? Schmorl proposed two reasons: First, it is approximately here that the elastic gelatinous nucleus is most active (although it is actually placed slightly posteriorly); secondly, here the adjacent vertebra is the weakest, because of the multiple small perforations located centrally in the bony plate.

Ballooning of discs occurs chiefly in the lumbar and lower thoracic regions, for here the discs are larger and apparently have more expansile force than in other regions (Figs. 2-A and 2-B). The stress is directed vertically, and less in the curved direction which is seen higher in the thoracic region. In the thoracic portion of the spinal column, while ballooning may occur to some extent, the chief deformity is usually a wedging of the vertebrae with the lower height anteriorly. Here, because of the kyphosis normally present, the anterior edges of the vertebrae take most of the force, and compression often occurs (Fig. 3).

Five patients in this study showed evidence of moderate to marked ballooning. One was forty-nine years old. The others were all in the sixties. Three were men and two were women (although osteoporosis is more common among women than among men). Microscopically, the following changes were observed. The vertebral bodies showed lessening in number and width of the trabeculae. The discs were larger than normal, but less dense, for the same amount of tissue had an added amount of fluid to take up the space formed by the expansion of the disc. The nucleus showed very little evidence of degeneration, and its tissue substances were separated by fluid. Many small cavities and vacuoles were found. The annulus was stretched, and more spherical than usual. Donohue stated that rupture of the cartilaginous plate is frequent and prolapses without reaction are common. However, we found no more defects of the cartilaginous plate or microscopic protrusions of nuclear material in the ballooned discs than in other discs of a comparable age group. The cartilaginous plates did not seem to be thinned, though this was questionable in some specimens. Thus from our observations the discs were in as good a condition as those of comparable age groups where ballooning did not occur, and, except for their increase in size, might fall within the norm for their age. This is due in turn to their increased fluid content, which causes a looser arrangement of the cellular elements in the disc.

FIG. 3

Ballooned intervertebral disc from the thoracic portion of the spinal column of a woman, aged seventy-seven years, suffering from osteoporosis. (× 3.5.)

D. THINNED DISCS

While it is recognized that thinning of the intervertebral disc is relative, the diagnosis can be made rather definitely by roentgenographic examination or by examining a microscopic section grossly. Both methods have been used in this study, and only when both show moderate to marked thinning have the discs been termed pathological. Nine of the eighty-eight specimens in this study showed thinning of the disc. Horwitz, examining the spinal columns of seventy-five cadavera grossly, found fifty that showed evidence of lumbosacral narrowing. His subjects were aged forty-five to ninety years. There are three obvious reasons for the discrepancy in incidence of thinning: (1) In this study a double check was made, as indicated previously, in order that only definitely thinned discs should be used for microscopic examination; (2) many of our subjects were below the age of forty-five years, when thinning is less common than at greater ages; and (3) only moderate to marked thinning of the lumbosacral disc has been considered in this study. The majority of the thinned discs found in this study are in the fifty-year to seventy-year age groups, however, and none were found below the age of twenty-one years.

What is the causation of the thinned disc? Microscopically, they may be classified into two groups. Group 1 is made up of those in which the annulus and the cartilaginous plate are intact, and in which there is no evidence of invading fibrous and granulation tissue. Three of the specimens fall within this group. There are desiccation and necrosis of the nucleus pulposus. Apparently the fluid content of the disc has been markedly diminished; and, as fluid normally comprises a high percentage of the total volume, there is loss of actual space-occupying material in the disc. The disc, therefore, becomes collapsed and smaller than normal. The roentgenograms in this group show thinning, with very little marginal sclerosis of the end plate and very little hypertrophic spurring (Fig. 4,*a* and *b*).

Group 2 consists of thinned intervertebral discs in which the cause of the thinning is more evident than in Group 1. Either the annulus is ruptured, usually posteriorly, or the

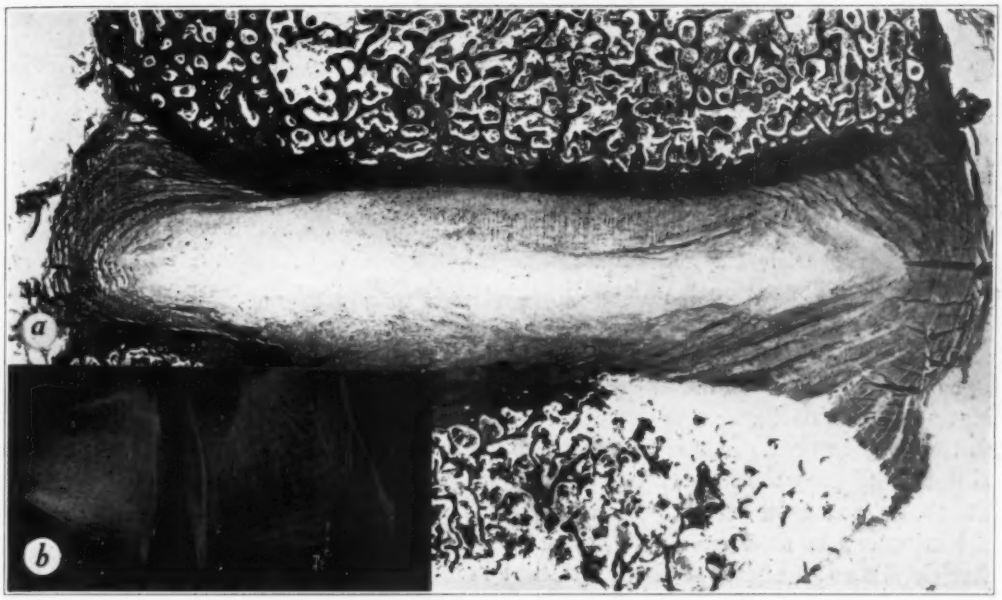

FIG. 4

Thinned intervertebral disc of a woman, aged twenty-nine years. *a*. Section (× 5). The loss of substance in the lower anterior aspect is an artefact. *b*. Roentgenogram.

cartilaginous plate contains many defects, or both. Six of nine cases fall in this group. The nuclear material flows out through these openings in the annulus or cartilaginous plate, with resulting loss of disc tissue and consequent thinning. This is a purely mechanical phenomenon. In addition, blood vessels and fibroblasts invade the disc through the openings in the annulus or cartilaginous plate, and this may "open avenues for dehydration of the disc" as Compere and Keyes have emphasized. In time these invading cells may completely replace the normal cells of the disc. Figure 5,*a* and *b* is an example of the second type of thinned disc. The roentgenograms in this second group invariably show some marginal sclerosis, and fairly frequently they show osteophytic reaction.

Dehydration is the essential cause, then, of the thinning of the disc. Why this occurs in Group 1 is not entirely clear. We have shown that in Group 2 it is due to the invasion of the disc material by blood vessels and fibrous tissue, opening avenues of dehydration. These invade the disc through defects in the annulus and in the cartilaginous plate. The cause of these defects has been discussed elsewhere. It should be emphasized here that Pease has shown how the penetration of the posterior portion of the annulus with the lumbar puncture needle can result in thinning of the disc. Gellman has also reported a case of injury to the disc in this same manner. Thinning of the disc by infection is another problem and will be discussed later.

To complete this picture of the thinning of the disc, the end result should be discussed. One of the specimens in this study (Fig. 6,*a* and *b*) showed complete obliteration of the disc, with resulting bony ankylosis. This was probably not the usual picture, for most lumbosacral discs, though they may be almost completely destroyed, are usually not invaded by bone, and ankylosis of the fifth lumbar to the first sacral segment is uncommon. The almost complete destruction of the disc, with bony ankylosis, is more likely to be the result of spondylitis deformans or of infection. The specimen shows bony continuity between the adjacent vertebrae, with islands of disc tissue remaining here and there. Very little of the annulus fibrosus remains, but there are intact regions of cartilaginous plate and occasional nests of nuclear material. The roentgenogram confirms the bony ankylosis between vertebrae. Schmorl emphasized that once ankylosis has occurred, its cause cannot be determined microscopically or roentgenographically.

E. INTRASPONGY NUCLEAR HERNIATIONS ("SCHMORL BODIES")

A Schmorl body may be defined as the herniation of disc substance through the cartilaginous plate into the body of the adjacent vertebra. Known also as Schmorl node or nodule, disc prolapse, cartilage node, or intraspongy nuclear hernia (Calvé and Galland), this phenomenon was first described by von Luschka in 1858, and "rediscovered" by Schmorl in 1927. The herniation occurs through a defect in the cartilaginous plate, and extends a varying distance into the cancellous bone of the adjacent vertebra. In youth the defect in the cartilaginous plate is probably partly developmental. Herniations occur in a row, opposite the region of greatest nuclear expansion. They are usually quite uniform in size and shape. In older spinal columns they tend to be single, to pass through larger defects in the cartilaginous plate, and to be highly irregular in size and shape. A reactive change occurs in the bone around the herniation, usually in the form of bony sclerosis. The prolapse itself tends to change over to cartilage, especially at the periphery, and even tends to ossify in time. This is thought to be nature's way of attempting to solidify the herniation, and plug the hole through which the disc escapes. Granulation tissue often grows from the marrow into the disc by way of the herniation. This vascularization and cicatrization can be seen grossly as dark reddish infiltration of the nucleus pulposus. For further details as to anatomy of the Schmorl body, one may read excellent descriptions by Schmorl, Beadle, Calvé and Galland, Sashin, Donohue, and others.

These herniations occur in the spinal columns of young persons rather rapidly after trauma because of the turgor present in the disc. But in the spinal columns of older persons, with loss of fluid in the nucleus, the herniation probably occurs gradually, and is due to the actual force of the cephalad vertebra on the caudad vertebra, with the disc interposed, so that a "squeezing out" process occurs. Schmorl bodies have been produced experimentally among dogs by producing defects in the cartilaginous plate.[8]

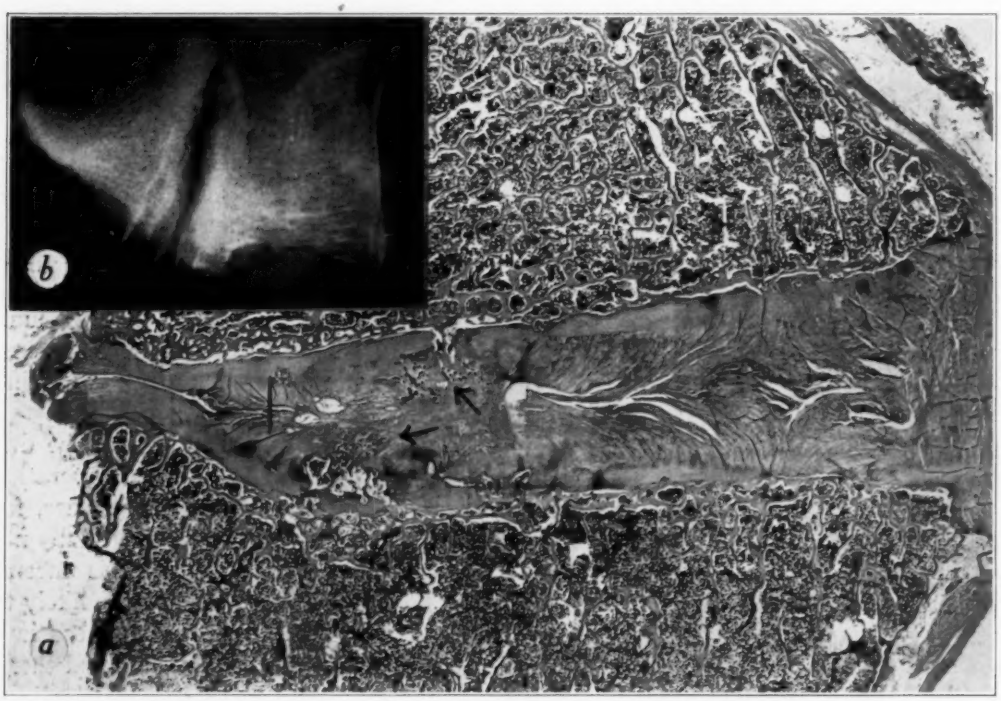

FIG. 5

Thinned intervertebral disc of a man, aged seventy years, with marked sclerosis of adjacent vertebrae. *a*. Section (× 3.5). Arrows point to invading blood vessels. There is posterior protrusion of nuclear material. *b*. Roentgenogram.

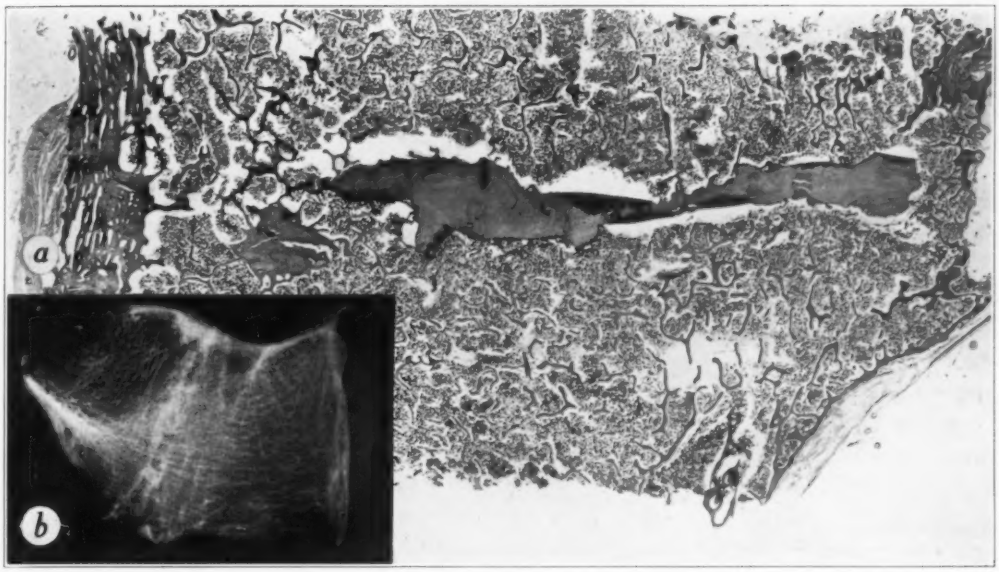

FIG. 6

Obliteration of intervertebral disc of a woman, aged sixty-five years, and consequent bony ankylosis. *a*. Section (×4). *b*. Roentgenogram.

The herniation must be more clearly defined, in order that the facts of this study may be presented. Beadle stated that herniations just visible to the naked eye are the smallest that should be included. However, he also stated that prolapses may be just through the cartilaginous plate, and these are usually not visible to the naked eye. Our study includes all prolapses that can be seen grossly or microscopically. A tear, through which there streams out nuclear material which stops at the bone of the vertebra, is included here as a herniation.

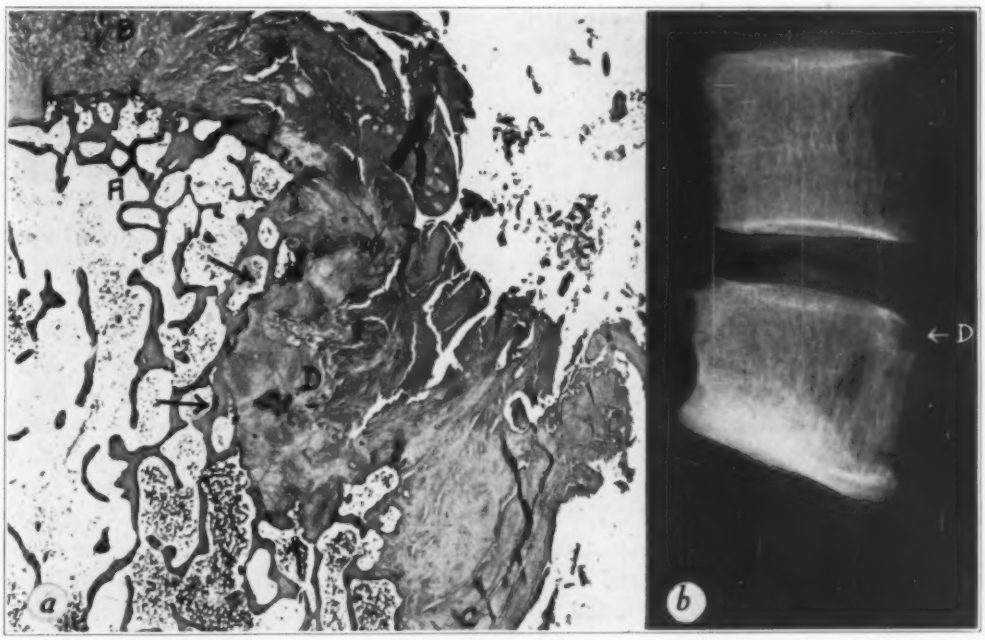

FIG. 7

Intervertebral disc of a woman, aged sixty-eight years. *a*. Section (×9): *A*: Bony rim. *B*: Anterior portion of annulus fibrosus. *C*: Anterior longitudinal ligament. *D*: Protruded nuclear material. *b*. Roentgenogram. *D*: Protruded nuclear material.

TABLE II
INCIDENCE OF MICROSCOPIC INTRASPONGY HERNIATIONS

Decade	Specimens	Herniations	Herniations (*Per cent.*)
1	5	0	0
2	6	1	17
3	8	2	25
4	9	5	55
5	11	8	73
6	22	18	82
7	16	14	87
8	11	8	73
	88	56	63.63

Schmorl found that herniations occurred in 38 per cent. of all spinal columns examined by him. Batts in a postmortem study of gross specimens found 20 per cent. of spinal columns showing herniations visible to the naked eye. The present study concerns itself only with the lumbosacral region, and only with microscopic and roentgenographic studies. In eighty-eight specimens, only two showed herniations large enough to be seen in a roentgenogram (Figs. 1,*b* and 7,*b*). Three additional sections showed herniations large enough to be seen grossly, if the slide was held up to the light. However, by far the majority of sections examined showed multiple microscopic herniations, most of them passing through the cartilaginous plate and ending just after penetrating the bone. Table II shows the incidence of these microscopic herniations.

This is evidence that the protective forces at play are great, and that only a relatively few herniations actually pass very far into the adjacent vertebral bodies. These defects of the cartilaginous plate with microscopic herniations probably are not very serious in themselves. They are so frequent, especially in the later age groups, as to be almost normal.

Two requirements are necessary for an intraspongy nuclear herniation to be visible on a roentgenogram: (1) The herniation must be large enough to be seen with the naked eye; and (2) there must be enough sclerosis around the margin of the herniation to cast a shadow of increased density to the roentgen rays.

One of the sections in this study had a nuclear herniation into an adjacent vertebra which had been invaded by metastatic carcinoma (Figs. 8-A and 8-B). The herniation is almost spherical and comes through a very small defect in the cartilaginous plate. The herniation contains chiefly degenerated nuclear material. There is very little proliferation of cartilage cells, or other reaction. The bone of the vertebra is almost completely gone and has been replaced by loose, oedematous granulation tissue. Next to this tissue is the metastatic carcinoma (prostate). This is an excellent example of what happens when the cartilaginous plate breaks, and there is no force on the opposite side to prevent herniation of the nucleus. Not only does the nuclear material extrude into the destroyed vertebral tissue, but the normal reactive processes of the body are lost and a walling-off process cannot take place.

Though this is not in any way a clinical study, we should like to summarize the opinions regarding the clinical significance of Schmorl bodies. Schmorl believed that they were not the cause of clinical symptoms, though he had very few clinical data to work with. Donohue stated that the majority did not evoke clinical symptoms. Geist, on the other hand, expressed the opinion that they do cause clinical symptoms. The probable answer is that the herniation itself is not particularly painful, but that the symptoms are caused by the result of the herniation, as has been suggested by Schanz. If much of the disc tissue escapes, and the disc becomes degenerated and thinned, added strain is placed on the ligaments about the disc. Also, the axis of motion may be displaced posteriorly, as suggested by Keyes and Compere, placing the strain on the articular facets.

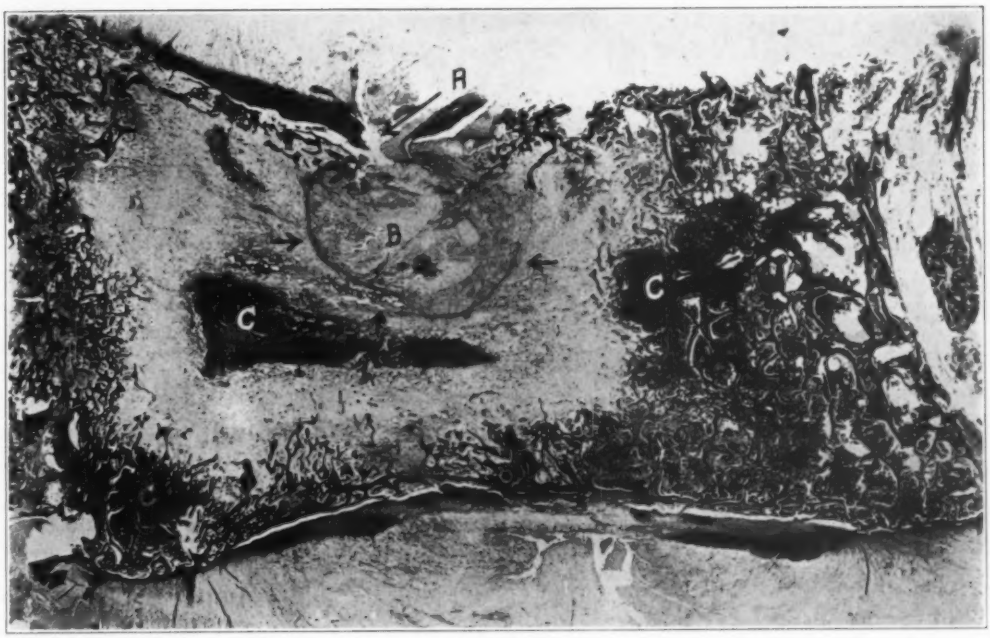

FIG. 8-A

Schmorl body in a vertebra of a man, aged seventy-five years, suffering from metastatic carcinoma. *A*: Break in cartilaginous plate. *B*: Protruded nuclear material (Schmorl body). *C*: Metastatic carcinoma. (× 3.5.)

F. ANTERIOR NUCLEAR PROTRUSIONS

The rarest of all nuclear protrusions (6 per cent. of fifty spinal columns examined by Batts), and probably least important from a clinical standpoint, is the anterior protrusion of the intervertebral disc. Several of our specimens showed an anterior bulging of the whole disc substance, but this can hardly be classifiable as protrusion or prolapse of the disc. One specimen, from a woman, sixty-eight years old, shows very clearly an actual anterior protrusion of nuclear material from the lumbosacral intervertebral disc (Fig. 7,*a* and *b*). The protruded substance streams over the anterior edge of the first sacral segment and dissects along the border between the ligament and the bone for one centimeter or so. There is an associated break in the anterior longitudinal ligament, but this may be an artefact. The protrusion consists chiefly of desiccated nuclear material, with much reaction in the form of new cartilage nests along the border. There is an attempt at penetration into the marrow spaces, which is almost an erosion; and there is evidence of invasion of granulation tissue into the prolapsed material.

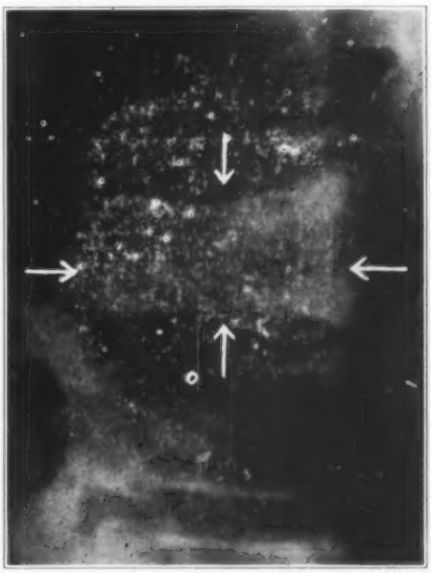

FIG. 8-B

Roentgenogram of the vertebra shown in Fig. 8-A. The arrows indicate the affected vertebra.

The disc itself is severely degenerated, with very few normal cells remaining. There is a large horizontal cavity. No actual thinning is observed. The roentgenogram is interesting,—the anterior bulge of the annulus can be seen, beneath which is the actual rup-

tured nuclear material; it appears to have eroded into the anterior superior margin of the vertebral body.

G. POSTERIOR NUCLEAR PROTRUSIONS

Posterior protrusion of the intervertebral disc is an entity which was recognized as early as 1858, when von Luschka first discovered it. Goldthwait, in 1911, described in detail a case of posterior protrusion of a disc. Schmorl, in 1929, rediscovered posterior protrusions. Bradford and Spurling, in their monograph on intervertebral discs, gave credit to Mixter and Barr for presenting the first adequate description of the full clinical picture of protruded discs.

This study does not deal with gross specimens, as seen at necropsy. However, by microscopic study several discs were observed which clearly indicated that there had been rupture of the posterior portion of the annulus fibrosus with herniation of disc tissue into the spinal canal.

Trauma is thought to be the cause of posterior protrusion, with degeneration of the annulus as a predisposing factor. Beadle stated that posterior protrusion of the disc is never encountered when the patient is less than thirty years of age, and that it rarely causes symptoms. Both these statements have been proved incorrect in the light of present experience. In many cases in which acute posterior protrusion of a disc is encountered clinically, the patient is less than thirty years of age. The incidence of posterior protrusion has been put by Beadle at 15.2 per cent. of all spinal columns examined at necropsy. Batts found 16 per cent. of posterior rupture in an examination of fifty spinal columns. Horwitz, examining seventy-five cadavera, found that fifty showed posterior bulging, but that only four had evidence of posterolateral protrusion. Love and Walsh have found that 96 per cent. of protrusions occur in the lumbar region.

Seven of eighty-eight specimens (8 per cent.) examined microscopically in this study showed definite evidence of posterior protrusion,—that is, a rupture of the posterior portion of the annulus fibrosus with a loss of nuclear substance. It should be remembered that all ages are represented in this study, and that only lumbosacral discs were examined. The actual percentage of protrusion is undoubtedly higher, for the sections in this study were roughly midsagittal, and it is probable that many lateral protrusions were missed.

Figure 5,*a* shows a posterior protrusion in a thinned disc. Either the annulus fibrosus ruptures completely, or most of the fibers rupture, leaving intact only the outermost bands. These bands are seen to bulge markedly into the spinal canal. Through the opening so created are pushed the nucleus pulposus and fragments of the remaining annulus. This material shows dehydration and necrosis. In addition, hyperplasia of the cartilage cells occurs, so that the older protrusions are actually made up chiefly of cartilage. Bradford and Spurling stated that invasion of the disc by fibrous tissue and blood vessels is rare. Three of the seven cases in the present study showed invasion by blood vessels and fibrous tissue through the torn annulus into the disc substance. Calcification and ossification of the protruded material may occur. There was evidence of bone formation in one of the specimens. Deucher and Love, studying protrusions removed at operation, found much evidence of degeneration. Thirty-two per cent. of their specimens showed advanced degenerative change, most of it in the sixth decade.

Accompanying posterior protrusion of a disc is an actual loss of disc substance, and thinning occurs in many cases. Love and Camp, in a series of cases in which laminectomy was performed, found only a small percentage to have narrowing of the disc at the same disc level as the posterior protrusion. There was often narrowing at some other site than that of the protrusion. In two of the cases in the present study there was gross evidence of thinning. Between the two cartilaginous plates there was a cavity, created by the loss of nuclear material. Usually some nuclear material remains in the disc, and in most cases, is found on microscopic examination to be necrotic and pigmented.

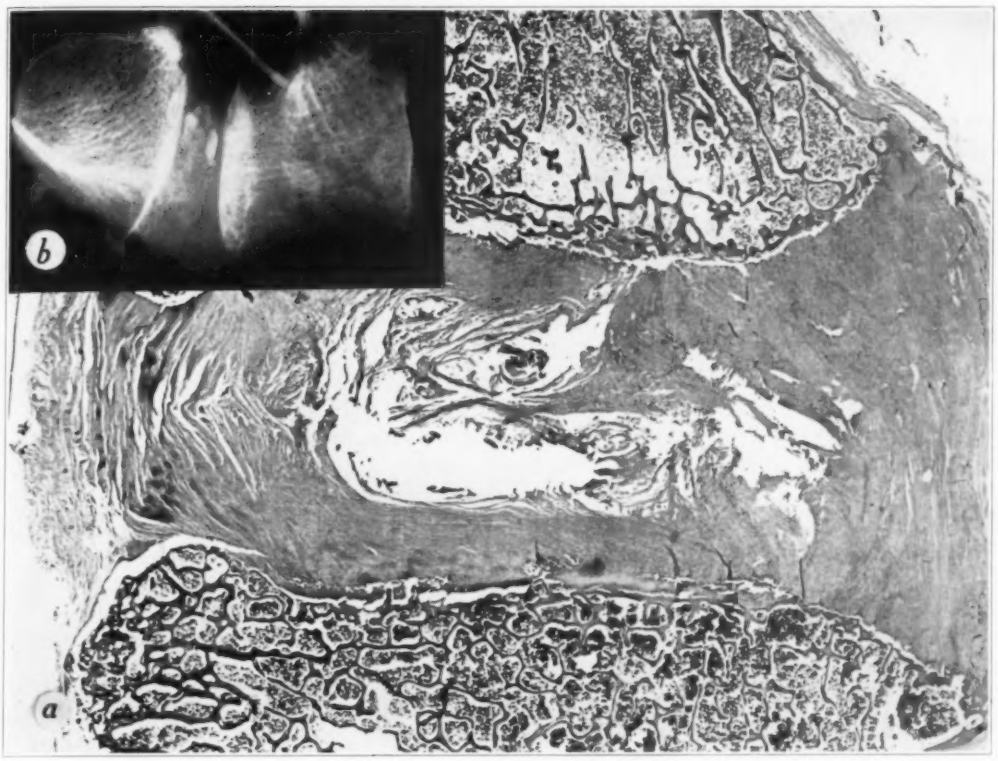

FIG. 9

Calcified nucleus pulposus of a woman, aged seventy-one years. *a*. Section (× 4). The calcium salts have been dissolved during preparation of the section, leaving space. *b*. Roentgenogram.

H. CALCIFIED NUCLEUS PULPOSUS

Deposition of calcium in the intervertebral disc takes several forms. Among older people there are large deposits beneath the cartilaginous plate; small nodes of calcium may be deposited in the plate itself or in the annulus; the nucleus itself may become completely calcified; or the entire disc may undergo calcification.

Calcification of the nucleus is recognized as a definite entity, not to be confused with other types of calcification. Calvé and Galland described it in 1922. The entire nucleus is converted into a mass of calcium salt. Microscopically the calcium is not seen, having been dissolved during preparation of the slide. In its place are strands of an amorphous residue.

One case of calcified nucleus pulposus was found in this study (Fig. 9). It showed the rest of the disc to be relatively intact for the age of seventy-one years, and there was no evidence of thinning. The roentgenogram revealed homogeneous, oval masses, congregated in the region of the nucleus; several of these masses were grouped together to form a cast of the nucleus pulposus.

Clinically, cases of calcification of the nucleus are important from only a differential viewpoint. Calvé and Galland stated that it is sometimes confused with Pott's disease. In Beadle's opinion, it may be mistaken for gouty deposits of uric acid.

I. INVASION BY INFECTION

The intervertebral disc is sometimes involved in infection. This is probably always a secondary involvement, the spread of infection coming either from the adjacent vertebrae through breaks in the cartilaginous plate, or down the longitudinal ligaments, or via the bloodstream. It has usually been thought that tuberculosis enters the disc from the ad-

jacent vertebrae. Cohn has recently shown that involvement of the disc commences early, usually by spread of the infection by way of the longitudinal ligaments. The annulus and nucleus pulposus are destroyed early. It seems probable that certain blood-borne infections may settle in the intervertebral discs, involving them before attacking the adjacent vertebrae. Brucellosis falls within this group. There are other types of infection involving the discs, in which the etiological agent cannot be identified, as pointed out by Ghormley, Bickel, and Dickson; and, as in brucellosis, thinning of the disc is an early sign of such infection. Reactive changes such as erosion and sclerosis adjacent to the disc sometimes occur.

Cases of infection involving the lumbar disc were not found in the routine examination during this study, but one of a man, aged sixty-five years, has been included in this report (Fig. 10). Necropsy showed vertebral osteomyelitis (staphylococcus aureus), secondary to extension down the psoas muscle from a subdiaphragmatic abscess. The microscopic section showed only about a fourth of the cartilaginous plate, the rest having been destroyed. There were no remains of annulus or nucleus, the space formerly occupied by them having been filled with exudate. The marrow spaces were invaded by polymorphonuclear leukocytes, plasma cells, and lymphocytes. The infection of the disc in this instance was clearly secondary to infection either in the bone or down the longitudinal ligaments.

FIG. 10

Vertebral osteomyelitis, involving an intervertebral disc of a man, aged sixty-five years.

J. INVASION BY A MALIGNANT LESION

According to Beadle, the intervertebral discs are very resistant to invasion by malignant lesions, even more than to infection. Various types of malignant lesions, sarcoma and carcinoma, primary and secondary, have been seen to involve almost all of the adjacent vertebrae, and still not to invade the disc. This is due to the resistive power of the cartilaginous plate.

Our study included only one case of malignant lesion,—a metastatic lesion in a vertebra from a carcinoma of the prostate (Figs. 8-A and 8-B). The body of the vertebra was rather completely infiltrated with malignant cells. There was a mild collapse of the body, as is seen in osteoporosis. One disc was touched in several places by invading carcinoma, but the cartilaginous plate was intact. On the other end of the vertebra, the opposite disc had protruded through a very small defect in the cartilaginous plate, and formed a large Schmorl body, extending halfway into the body of the vertebra. Beadle stated that most prolapses of this type are of the wide, oval variety, with much cartilage destroyed. This was not the case in our specimen, as the prolapse had a narrow neck and a round, smooth body. The prolapse contained chiefly nuclear material, severely degenerated. There was little attempt at proliferation of cartilage. Around the prolapse, between the metastatic carcinoma and the prolapse, was a clear zone of oedematous granulation tissue. No attempt of the carcinoma to invade this prolapse was noted, nor was any attempt at invasion of the discs by the carcinoma seen.

The roentgenographic appearance was characteristic of metastatic malignant lesions of the osteoblastic type. The metastatic lesions appeared more calcified than the adjacent bone, and thus more resistant to roentgen rays. Interestingly, the Schmorl body cannot be clearly seen in the roentgenogram, because of lack of reaction in the form of bone sclerosis surrounding it.

SUMMARY

The pathological changes studied in this series include hypertrophic arthritis, nuclear expansions, ballooned discs, thinned discs, nuclear herniations into the vertebrae (Schmorl bodies), anterior and posterior nuclear protrusions, calcification of the nucleus pulposus, infections of the disc, and invasion by malignant tumors.

Nuclear expansions are for the most part physiological, and not pathological; whereas ballooned discs are found almost entirely in the disease entity known as senile osteoporosis of the spinal column.

There are two types of thinned discs: one in which the cartilaginous plate and annulus are intact, the thinning being due to desiccation and necrosis of the nucleus pulposus, and the other type in which the annulus is ruptured, or the cartilaginous plate contains many defects. Dehydration is essentially the cause of thinning in both types.

Intraspongy nuclear herniations or Schmorl bodies are for the most part asymptomatic. Anterior nuclear protrusions are rare and of little clinical interest, whereas posterior nuclear protrusions are of great clinical importance. Eight per cent. of the specimens showed evidence of posterior nuclear protrusions.

Calcification of the nucleus pulposus is a definite entity. However, it is of no clinical significance.

Infection of the disc, resulting in early destruction of the annulus and nucleus, is recognized. The infection is usually blood-borne, and it may be primary or secondary to involvement of the vertebral body. The only example in this group was of infection of the disc, secondary to involvement of the vertebra.

Invasion of the disc space by a malignant lesion is rarely found. Only one example was observed in this series, and in this case no real invasion of the cartilage was seen.

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THE INTERVERTEBRAL FORAMINOTOMY FOR RELIEF OF SCIATIC PAIN

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Low-back pain with sciatic radiation has long been a problem to the orthopaedic surgeon. Pain in part of the sciatic-nerve distribution is frequently caused by some impinging mass squeezing or stretching one or more nerve roots. Herniation of the nucleus pulposus explains a large number of these cases. Our intention is: (1) to contribute toward the understanding of another large group,—those cases where there is impingement upon the nerve root within the intervertebral foramen; (2) to show what the various causes for such impingement may be; and (3) to outline the operative decompression.

The indications for simple laminectomy to relieve pain due to nerve-root pressure are generally known and accepted. However, during our surgical explorations seeking the oppressing medium, we encountered instances when there had been no hypertrophy of the ligamentum flavum, no concealed disc, and no herniation of the disc. In fact, no impinging mass could be found even after thorough visualization and palpation of the vertebral canal had been made. We were not alone in failing to find the lesion upon performing simple laminectomy. Hyndman, Steindler, and Wolkin reported that a small percentage of their patients, who presented definite symptoms and signs of root compression, including a negative Achilles tendon reflex, showed no herniated disc, concealed or otherwise.

About four years ago it occurred to the senior author (H.B.) that a complete exploration of the nerve root was not actually performed until that portion passing through the intervertebral foramen had been examined. Since that time we have employed a surgical procedure, which we have designated "intervertebral foraminotomy".

Our decision to make this exploration finds substantiation in the work of other investigators, among whom may be mentioned Nachlas, Oppenheimer, Hanflig, Breck and Basom, Horwitz and Smith, Bromer, Larmon, and Magnuson. The intervertebral foramen is a bone-lined duct the dimensions of which are only slightly altered under normal conditions. Any encroachment upon this space, beyond the physiological, will result in pressure upon the soft tissues contained within it. We wish to stress that examination of the vertebral canal by simple laminectomy is frequently not sufficient when one is looking for a cause of pressure upon a nerve root.

It is our common practice, when exploring the vertebral canal, to examine the ostium of the intervertebral foramen. When necessary, we have removed that portion of the articular process which overhung and obscured our visualization of the ostium. In many instances, that manoeuvre has uncovered small protrusions of the intervertebral disc. However, we do not consider that procedure to be an intervertebral foraminotomy. The entire foramen can be explored only by removing all or a large part of both articular processes.

The surgical technique employed is largely that reported by Williams and Yglesias, Ghormley, and Mitchell as facetectomy. We have employed the phrase "intervertebral foraminotomy" because it describes more aptly the surgery performed. A closed canal is actually converted into an open trough. The exposure of the vertebral column is carried out to beyond the articular processes; bleeding is controlled by pressure and electrocautery if necessary. The ligamentum flavum on the affected side is then removed in its entirety. If there is insufficient interlaminar space in which to perform good exploration, adjacent portions of the laminae are removed to increase the space. In order to open the intervertebral foramen, the facets with their articular processes are removed. Both rongeur and osteotome are employed for this removal of bone, which must be done slowly

and carefully, only small pieces being removed with each bite. When the osteotome is employed, the bone involved is always backed up by a suitably sized curette in the hands of the assistant. In that way, bone fragments are not pushed into adjacent soft tissue. The field is kept clear of bone bleeding by suction. Sufficient bone, ligamentum flavum, and capsule are removed to visualize the nerve root along its entire course until it passes into soft tissue. The lesion is removed; operation is completed by placing a small piece of muscle tissue over the exposed nerve root, and fusion is performed, employing the chip fusion described by Briggs and Milligan. The patient is returned to bed, and the postoperative course is that followed routinely for a simple spine fusion.

The senior author has been the responsible surgeon in thirty-five operations where intervertebral foraminotomy has been a part of the surgical procedure. In this group the following lesions were found: (1) diminution of foraminal space, secondary to diminution of the intervertebral disc space; (2) hypertrophic lipping of the posterior periphery of the vertebral bodies (this hypertrophy was often cartilaginous, and did not show on roentgenograms); (3) herniation of the intervertebral disc into the intervertebral foraminal space; (4) nuclear material impacted within the foramen, which seemed to have migrated from some distant point of herniation.

In the first condition, diminution of the foraminal space, secondary to diminution of the intervertebral disc space, our series includes twenty-two cases. In these, simple unroofing of the intervertebral foramen has been found to be sufficient; the nerve root lies in a space of greater dimensions. Adequate space has been provided by the removal of the articular processes, and in some cases a portion of the pedicle, so that a trough was formed. Occasionally the nerve root was bound down by adhesions. These were gently released, and the nerve root was seen to lie free before the operation was completed.

One such case is of a man aged forty-eight. Seven years earlier he had undergone surgery at this Hospital for removal of a ruptured intervertebral disc. At that operation the herniation was found and removed; lumbosacral fusion, employing a tibial graft, completed the operation. The patient remained free from symptoms for seven years. Six weeks prior to his latest admission to the Hospital, there was sudden return of the original unilateral sciatic pain. This pain became increasingly severe. Neither manipulation, bed rest, nor brace immobilization gave any relief. Only large doses of narcotics were of any avail. Roentgenogram showed a complete collapse of the fifth lumbar disc space, as compared to a reported diminution of disc space seven years earlier. At operation we found that the graft had joined the involved vertebrae only by fibrous union. The bodies of the fifth lumbar and first sacral vertebrae were contiguous. The left fifth lumbar nerve root was oedematous, hyperaemic, and immobile. Intervertebral foraminotomy was performed, and adhesions binding the nerve root were broken. Within eight hours after the operation, there was considerable diminution of sciatic pain, and after forty-eight hours all narcotics were discontinued. A sense of weakness of the involved limb is present three months after the operation, but the patient has returned to work.

In those cases, seven in number, where hypertrophic lipping of the posterior periphery of the bodies existed, a second step was added to the unroofing procedure. We have gently lifted the nerve root free of its bed, and removed the hypertrophic portion plus a part of the parent body, with a small osteotome or curette. In our experience, this manipulation has not inflicted trauma to the nerve root leaving more than transitory symptoms.

The five cases which displayed frank herniation of the intervertebral disc within the confines of the intervertebral foramen were treated in the routine manner for such protrusions. The herniation was incised, and nuclear material was removed with curette and forceps. One such case displayed an interesting herniation which we should not have found without an intervertebral foraminotomy. The bulge in the annulus fibrosus was found to lie at the very periphery of the foramen as a posterolateral herniation. The bulging mass forced the nerve root to ride cephalad, squeezing it between the herniation and the pedicle of the fifth lumbar vertebra.

Free nuclear material impacted within the intervertebral foramen was found in one case. Subsequent diligent search revealed the original rent in the annulus fibrosus. The

point of rupture was just lateral to the posterior mid-line, about one inch distant from the loose nuclear fragment. Again we believe that this impinging mass could not have been recovered safely other than by foraminotomy. The patient immediately after surgery showed dramatic relief from intense sciatic pain. Prior to surgery, he had undergone all forms of conservative therapy, which gave relief only when accompanied by narcotics. Buck's bilateral traction gave relief only while traction was being exerted.

A small group of our cases, eight in number, had the intervertebral foraminotomy performed bilaterally. These patients complained of bilateral sciatic pain. They displayed a marked collapse of the intervertebral disc space, with simultaneous diminution of the foraminal space on both sides. Of this group, one patient had previously been subjected to mid-line laminectomies, in two separate operations, of the fourth and fifth lumbar vertebrae. Bilateral intervertebral foraminotomies at the lumbosacral junction gave immediate relief from sciatic pain, with persistent relief since operation. The patient's only complaint at present is that "pressure over the hole (laminectomy) in the spine is somewhat painful".

Our series of cases included intervertebral foraminotomies of the fourth as well as of the fifth foramen. When surgery involved the fourth space, fusion was performed to bridge only the fourth and fifth lumbar vertebrae. In this series, there is also one foraminotomy performed at the left side of the second lumbar intervertebral foramen.

This patient complained of pain radiating across the left mid-back and around to the abdomen. He had received a compression fracture of the body of the second lumbar vertebra, several years earlier. The radiating pain was of comparatively recent onset. Mid-line laminectomy with section of the sensory fibers of the second lumbar nerve root had failed to give relief for more than several months. We performed an intervertebral foraminotomy at the second lumbar space, exposed the nerve root, and permitted it to lie free. The patient has shown a decreasing degree of pain since that time, and is now symptom free.

The patients of this series have been seen regularly at intervals of six weeks to three months. The postoperative span for the individuals ranges from three months to four years. Relief from sciatic pain has been complete in all but three cases. One of this group insisted almost immediately after the operation that she had not been relieved. Undoubtedly the sciatica in this individual was not due to pressure upon the nerve root, with which we had been dealing. The other two are similarly unsolved problems.

It may be said that spine fusion, weeks of bed rest, use of a brace, or perhaps factors other than an intervertebral foraminotomy, gave the relief from pain. We do not feel that any of these factors are significant; for definite impinging masses were found in those cases in which foraminotomy was performed. Of our patients, 25 per cent. had been previously subjected to spine fusion with or without removal of a herniated disc. All of them had been subjected to long intervals of bed rest, use of a brace, and other conservative measures. All of those patients in whom good results were obtained, volunteered the information that the referred pain was relieved, or considerably reduced, immediately after operation.

We do not feel that the intervertebral foraminotomy has increased the operative risk or degree of complications, as compared to simple spine fusion with simple laminectomy. In our earlier experiences some cases showed slight residual muscle weakness or infrequent flashing pain in sciatic areas, for several days following operation. However, as our technique improved, we found that these evidences of nerve-root traumatization decreased in number. Our main regret is that the follow-up period is relatively short for many of the cases; we are waiting impatiently for the passage of the two-year, five-year, and ten-year periods.

Within our experience, we have formulated three indications for an intervertebral foraminotomy. They are as follows: (1) when simple laminectomy, with complete exploration of the accessible nerve root within the neural canal, has failed to reveal an imping-

ing mass; (2) complete or considerable collapse of the intervertebral disc space, with or without hypertrophic lipping as seen on the roentgenogram; (3) previous spine surgery, with or without fusion, which has failed to relieve the sciatic pain.

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CHRONIC MELIOIDOSIS

A Case Showing Multiple Lesions of Bones, Joints, and Lungs

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Melioidosis is an infective disease occurring in Burma, Ceylon, French Indo-China, the Dutch East Indies, Malaya, and Siam. Several hundred cases have been recorded since the original description of the disease by Whitmore and Krishnaswami in 1912. In the vast majority, the disease has been acute, with symptoms simulating cholera or enteric fever, and has proved fatal from septicaemia within a few days or weeks.[1,7,8,10] At autopsy, the commonest findings recorded in such cases have been areas of consolidation and small abscesses in the lungs, and abscesses or areas of caseation in the spleen, liver, and kidneys. Manson-Bahr records cases in which recovery from the primary attack was followed by a fatal septicaemia, and in which pulmonary lesions resembling tuberculosis were found at autopsy.

The chronic form of this disease is far less common. Five cases have been found in the literature, only two of them in Europeans. However, with the employment of large Allied forces in Far Eastern areas, where the infection is endemic, early recognition of its symptoms is of vital importance.

Melioidosis is recognized as a disease of rodents and man; it is generally assumed that infection in man is acquired from infected rodents, possibly by contaminated food or water supplies. The causative organism was named bacillus whitmori by Stanton and Fletcher in 1921, but was assigned to the pfeifferella group of bacteria by Topley and Wilson, and is now known as pfeifferella whitmori or malleomyces pseudomallei.

The following summary of five chronic cases is included in spite of previous appearance in the literature, because it is felt that some readers of *The Journal* may not have access to the original reports.

Case 1. An acute illness at onset in a native adult was followed by discharging sinuses, in both feet, which led to necrotic bone. Two years after the onset, the sinuses were still discharging, but the causative organism could no longer be isolated, and the general health of the patient was good.[11]

Case 2. An acute illness at onset in a native adult was followed by a discharging sinus over one lateral malleolus, from which pfeifferella whitmori was recovered repeatedly. Complete recovery ensued five months after the onset.[11]

Case 3. The patient was a native adult. An acute illness was followed by chronic involvement of the genito-urinary tract, and terminated in complete recovery.[9]

Case 4. A native infant had had no acute illness, but abscesses developed insidiously over one metacarpal and one parietal bone, with roentgenographic evidence of osteitis of the metacarpal. Complete recovery ensued after six months.[9]

Case 5. In a British soldier serving in Malaya, the history of onset was confused by a concurrent gonococcal infection which may have accounted for some of the earliest joint manifestations. Destructive bone lesions occurred in the bodies of the fourth and eighth thoracic vertebrae, associated with a paravertebral abscess, and there was also osteitis of one frontal bone and of one fibular malleolus, with abscess formation. The disease had not healed when the case was recorded two to three years after onset.[3]

Four of these five patients had one or more bone lesions, and three had had an acute illness at the onset. In each case, the diagnosis was made by identification of the causative organism.

The following is a further report of a case already presented by the author.[6] It is apparently the second to be recorded in a European, which fact would give rise to the theory

that Europeans have a greater natural resistance to the organism than natives. Although the first case was of considerable duration, that to be described presents by far the longest illness yet reported in this disease; the multiplicity of lesions also appears unique. Its importance lies, however, not so much in its rarity, but in its singular resemblance to tuberculosis. Since this case was incorrectly diagnosed for nearly three years, despite repeated bacteriological investigations, it seems highly probable that similar cases have remained — and may remain — unrecognized.

CASE REPORT

In July 1940, the patient, thirty-three years of age, a regular soldier in the British Army, was admitted to a hospital in Singapore, with a complaint of pain in the lumbosacral region, radiating down the thighs, especially the right. His symptoms had begun insidiously one month before admission. There was no history of tuberculosis or similar chronic disease in his family or contacts. Positive findings in the past history included empyema on the left side in early childhood, without sequelae, and an appendectomy at fifteen years of age. He had served in India from 1931 to 1937, during which period he had had attacks of dysentery, malaria, and tonsillitis. He had been in Singapore since 1938. In February 1940, he had had urticaria and swelling of finger and toe joints, which had disappeared after two months, following tonsillectomy and the administration of an autogenous vaccine.

Examination on admission showed no abnormal physical signs, except stiffness of the lumbar spine and enlarged rubbery inguinal lymph nodes, which on biopsy were negative. Roentgenograms of the lumbar spine and sacro-iliac joints showed no abnormality. The patient had an irregular pyrexia and heavy night sweats.

In August, flexor spasm of the right hip and slight wasting of the right buttock were noticed. At this time, the laboratory findings were:

Red blood cells,—5,800,000;
Hemoglobin,—66 per cent.;
White blood cells,—12,000;
Polymorphonuclear neutrophils,—72 per cent.;
Lymphocytes,— 24 per cent.;
Large monocytes,— 1 per cent.;
Eosinophils,— 3 per cent.;
Repeated blood cultures,—negative;
Wassermann reaction,—negative;
Widal reaction,—positive only in very low titre;
Stools,—negative for ova, cysts, and occult blood;
Urine,—negative except for a few leukocytes.

During the next few months, the patient's general condition deteriorated. His fever subsided temporarily with the administration of sulfapyridine. In October, his sedimentation rate was sixty millimeters per hour, but fell to twenty millimeters (method not stated) during the following month. A tentative diagnosis of ankylosing spondylitis was made.

In January 1941, a lumbosacral abscess developed, culture of which was negative. During the following month, an abscess developed in the right sacro-iliac region, from which vibrio alkaligenes was cultured. Injected guinea pigs died of a virulent septicaemia, and were reported negative for tuberculosis. The patient was kept recumbent, and showed slight improvement in his general condition.

The patient was transferred to a hospital in India where, in June, roentgenograms revealed slight rarefaction and loss of definition in the lower part of the right sacro-iliac joint. The Wassermann, Kahn, and Widal reactions were again negative, and the Weil-Felix reaction was positive only in low dilution against bacillus proteus O-X-19, O-X-2, and O-X-K. In July, bilateral sacro-iliac abscesses developed, which were sterile on aspiration, but from the drainage of which staphylococci were grown. Injected guinea pigs were reported to have died of staphylococcus septicaemia. The diagnosis was now changed to tuberculous sacro-iliac arthritis, with secondary infection.

In August, following roentgenograms which showed destruction of the right sacro-iliac joint, a bilateral hip spica cast was applied.

In May 1942, roentgenograms showed collapse of the body of the eighth thoracic vertebra with a large paravertebral abscess and no narrowing of the intervertebral discs, slight sclerosis of the adjacent vertebral bodies at the lumbosacral joint with narrowing of the disc space, extensive infiltration at the base of the right lung, bilateral hilar enlargement, and bilateral apical pleural thickening. The laboratory findings at this time were:

Red blood cells,—5,400,000;
Hemoglobin,—60 per cent.;

White blood cells,—6,400;
Polymorphonuclear neutrophils,—52 per cent.;
Lymphocytes,— 45 per cent.;
Large monocytes,— 3 per cent.;
Sedimentation rate,—110 millimeters per hour (Westergren);
Urine,—negative;
Repeated sputum examinations,—negative for tuberculosis.

The patient, recumbent but unsplinted, was now transferred to a hospital in South Africa. He continued to have low backache, pain in the right lower extremity, and intermittent pyrexia. He had an angular kyphosis at the eighth thoracic segment, and a deformity and pain on motion at the right hip. There was poor expansion of the right side of the chest, with bronchial breathing over the lower lobe and dullness of the middle lobe. The diagnosis was multiple tuberculous arthritis and tuberculous bronchopneumonia. In July 1942, a right psoas abscess developed, culture of which showed numerous gram-negative bacilli, and, in August, there was a single large hemorrhage from the intestine, the cause of which was not discovered. In October 1942, roentgenograms showed destruction of the right femoral head and of the acetabular roof with adduction and dislocation, destructive changes in the right sacroiliac joint, increased irregularity of the surfaces at the lumbosacral junction, increased wedging of the eighth thoracic vertebra, slight clearing of the right lung, and slight mottling of the left lung. The patient continued to have fever in irregular attacks, and a pulse rate which varied in proportion to his temperature. The right lower extremity was placed in traction, to correct the adduction deformity of the hip. In December, the hip was manipulated into an improved position and immobilized in a plaster cast. In January 1943, a cold abscess of the right buttock developed and slowly subsided.

Shortly after the author had taken over the case in April 1943, a large abscess of the anterior aspect of the right thigh was discovered when the cast was changed. Aspiration yielded thin, diffusely blood-stained pus from which pfeifferella whitmori was isolated for the first time by my colleague, Major M. H. Finlayson. Agglutination was positive at a dilution of 1 to 500. Negative laboratory examinations at this time included the sputum; urine; culture of urine and faeces for pfeifferella whitmori; blood culture; Wassermann, Kahn, and gonococcal complement-fixation tests; and agglutination tests against organisms of the enteric, brucella, and proteus groups.

FIG. 1-A

May 1943. Anteroposterior view of the lower thoracic spine, showing the collapsed eighth thoracic vertebra, the paravertebral abscess, and slight narrowing of the disc between the eleventh and twelfth vertebrae. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

FIG. 1-B

May 1943. Lateral view of the lower mid-thoracic vertebrae, showing wedge-shaped collapse of the body of the eighth vertebra with clear definition of both adjacent intervertebral discs, which are of practically normal width. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

FIG. 2

May 1943. Anteroposterior view of the right hip joint. The femoral head is dislocated and almost entirely destroyed; and the acetabular roof has also been involved in the destructive process. Despite the roentgenographic appearance suggesting bony fusion, ankylosis was clinically unsound. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

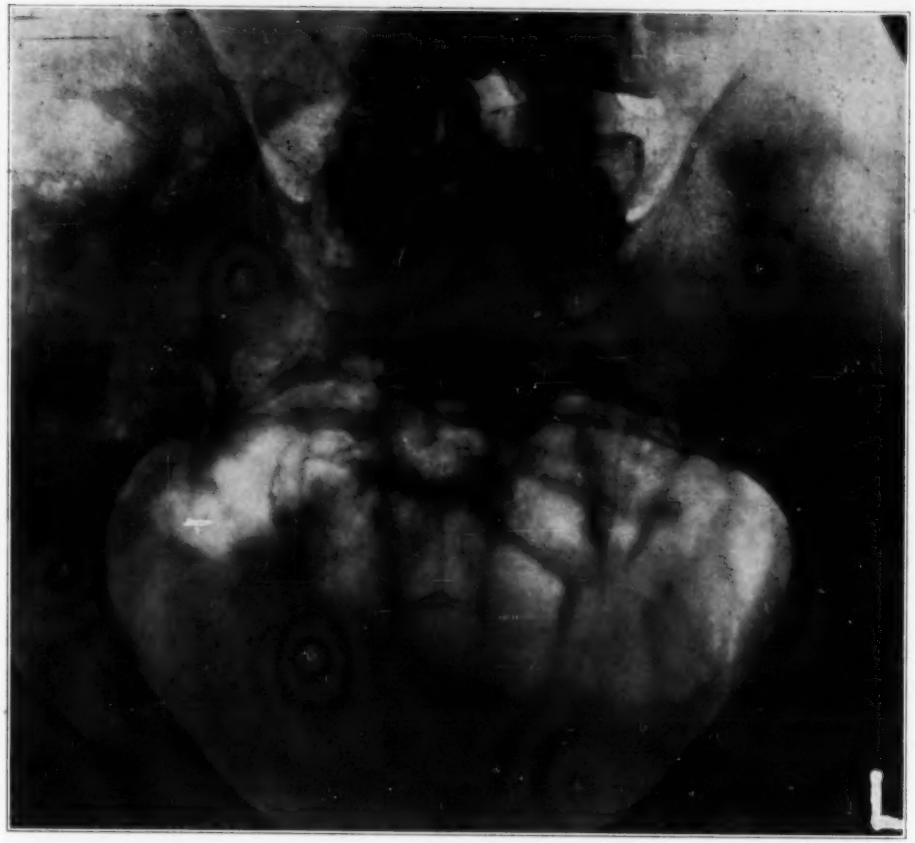

FIG. 3

May 1943. Anteroposterior view of the sacro-iliac joints. The appearances of bone destruction in the right joint were constant in several roentgenograms taken at different dates, and are, therefore, not due to overlying gas shadows. There is loss of definition of the joint surfaces and apparent obliteration of the joint space near its center. Similar changes are suggested on the left side, where fusion appears to be taking place. Patchy areas of sclerosis and of decalcification are also visible. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

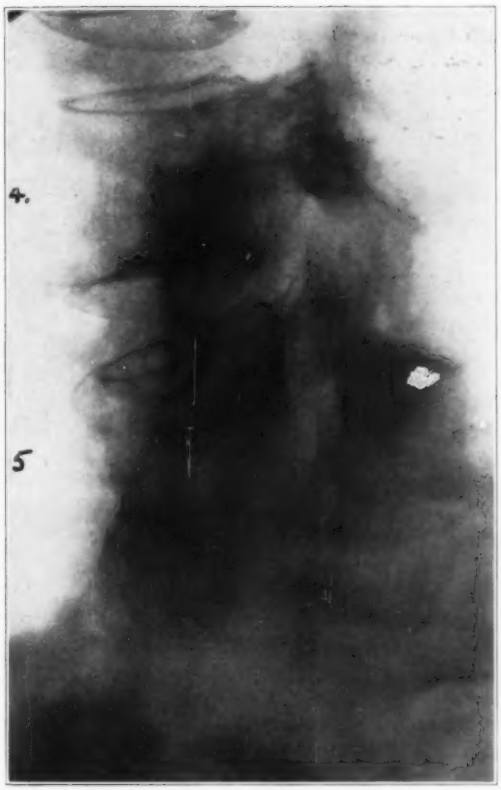

FIG. 4

May 1943. Lateral view of the lumbosacral joint, showing narrowing and loss of definition of the joint space. Extensive decalcification prevented more distinct roentgenography.

FIG. 5

February 1944. Lateral view of the thoracolumbar spine, showing narrowing of the discs, without bone destruction, between the eleventh and twelfth thoracic vertebrae, and between the first and second lumbar vertebrae; the twelfth disc appears slightly widened anteriorly.

The patient was treated with autogenous vaccine, by hypodermic injections of 10,000,000 dead organisms; the dose was increased fairly rapidly at biweekly and later at weekly intervals. Several additional abscesses and sinuses developed about the sacrum and groin during the next month, characterized by blood-stained, "anchovy-sauce pus" which, on culture, showed pfeifferella whitmori. Roentgenograms also showed narrowing of the disc space between the eleventh and twelfth thoracic vertebrae. After the dose of vaccine had been increased to 400,000,000, each injection was followed by increased fever a few hours after the inoculation and a slight local reaction at the site. The patient had a microcytic anaemia, and continued drainage from the thigh abscess, but showed general improvement. As Finlayson had shown experimentally that urea was lethal to pfeifferella whitmori *in vitro*, a saturated solution of urea was used for irrigating the persistent sinus in the thigh, but this had no appreciable effect. Sulfadiazine then became available, and was given with apparent beneficial effect on the fever and general condition. A total of forty-five grams of the drug was administered over a period of four weeks without harmful effects. Vaccine therapy was stopped in January 1944, after a maximum weekly dose of 2,500,000,000 organisms had been reached.

By April 1944, all of the sinus tracts had healed. The patient was gaining weight, and had been completely afebrile for three months. His hemoglobin had increased to 97 per cent., and his sedimentation rate had fallen to twenty-six millimeters per hour (Wintrobe). Roentgenograms in February 1944 showed narrowing of the disc space between the first and second lumbar vertebrae, while the chest appeared normal and the lesions in other areas were unchanged. As there had been little sign of spontaneous fusion of the hip, it was thought that arthrodesis would be necessary later. The prognosis was considered favorable for recovery.

Bacteriological Findings

A detailed account of the bacteriological findings in this case has been published previously.[2] I am indebted to Major Finlayson for the following summary.

Morphology and Staining: The organism is a gram-negative, non-sporing, motile bacillus, measuring about one-half to two micra, without evidence of capsule formation. It shows polar staining, but is rather poorly stained by the simple aniline dyes, Neisser's, Albert's and Leishman's stains. Good differentiation was obtained by staining with dilute carbolfuchsin and counter-staining with dilute methylene blue; this method showed red granules on the blue background of the bacillus. In the tissues of inoculated animals, the bacilli were well demonstrated by carbolthionin, and appeared longer and narrower than on culture, sometimes showing short chain formation.

Cultural Characteristics: On blood agar, the organism produced a fine growth after twenty-four hours' incubation, becoming abundant, smooth, gray, and glistening after seventy-two hours' incubation. The organism was also grown in nutrient broth, nutrient gelatine, Loeffler's serum, milk, and McConkey's agar. It fermented glucose without gas formation; failed to ferment lactose, dulcite, saccharose, and mannite; decolorized Andrade's indicator after forty-eight hours' incubation; formed no indole in peptone water; and did not grow on ordinary media under anaerobic conditions.

Animal Experiments: Intraperitoneal injection of 0.5 of a cubic centimeter of a twenty-four-hour broth culture killed a guinea pig in thirty hours, and produced a copious, glairy, peritoneal exudate from which pfeifferella whitmori was grown. The infection was widely disseminated, and caused many visceral lesions. Similar effects followed the injection of mice.

Serological Reactions: Agglutination tests were positive with the patient's serum at a dilution of 1 to 500; were negative with two normal sera at a dilution of 1 to 25, and were positive with the sera of several patients suffering from proved chronic pulmonary tuberculosis in dilutions up to 1 to 50.

Conclusions: Except for its acid-fast properties, the general characteristics of this strain resemble in every respect those described as pfeifferella whitmori by Stanton and Fletcher, and by Topley and Wilson.

DISCUSSION

In retrospect, it is possible to criticize the earlier diagnosis of tuberculosis. The persistent pyrexia at the onset of the disease, despite complete rest, with abscesses developing seven months later, but with roentgenographic changes appearing only after a further lapse of five months, should have been viewed with suspicion. Also atypical was the wedge-shaped collapse of a single thoracic vertebra, without appreciable narrowing of the adjacent intervertebral discs or involvement of neighboring segments. The anomalous bacteriological findings in earlier specimens of pus suggest that pfeifferella whitmori (or malleomyces pseudomallei) may have been present, but had escaped detection. Repeated failure to find bacillus tuberculosis in the sputum had not been explained, but the pulmonary lesions had been regarded as typical of tuberculosis clinically and roentgenographically. This is the only known chronic case showing pulmonary lesions.

The right sacro-iliac lesion may have started either as arthritis, or as juxta-articular osteitis. The extensive destruction of the upper end of the femur suggests that the hip lesion began as an osteitis, and the lesion of the eighth thoracic vertebra was obviously an osteitis. On the other hand, there appears to have been no bone destruction associated with the lesions between the eleventh and twelfth thoracic and between the first and second lumbar vertebrae, both of which are definitely attributable to melioidosis, since earlier roentgenograms of these regions were normal. The lumbosacral lesion appears to have a similar pathology. Thus it seems that some of the lesions primarily involved bone and others cartilage. Much of the patient's improvement may be attributed to the combination of autogenous vaccine and sulfadiazine therapy. While the latter was perhaps more dramatic in effect, it was first employed at a time when the patient might have been expected to improve because of better drainage. Furthermore, general improvement had been noted with vaccine therapy before the use of sulfadiazine, and improvement continued with vaccine therapy after the sulfadiazine was stopped. Therefore, it seems that these agents, used in combination, are valuable. Urea, despite the experimental *in vitro* evidence, was of no apparent value, but this may have been due to the impossibility of achieving adequate contact between the urea and the osteo-articular infection.

An important principle in the treatment of melioidosis is that the abscesses, unlike those of tuberculosis, should be drained early and adequately. Abscess formation was ac-

companied on each occasion by a deterioration of the general condition, which improved following the institution of adequate drainage. Imperfect drainage was always accompanied by the formation of a chronic sinus, but, when good drainage could be established, healing was not unduly delayed.

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THE USE OF SULFONAMIDES IN COMPOUND FRACTURES

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In recent years there have been numerous articles in the medical literature dealing with the treatment of compound fractures. It seems generally agreed that most of the compound fractures occurring in the war zones are best treated by leaving the wounds open. However, in civilian injuries, it is felt by many that, following an immediate irrigation and débridement, suture of the contaminated wound is a logical procedure in selected cases. Such factors as the extent of tissue damage, the amount of gross contamination, the time elapsed since the injury, *et cetera*, are of importance in deciding whether or not this initial suture is advisable. These same factors are of importance in the incidence of infection in these primarily closed wounds. The implantation of one of the sulfonamides in the wound at the time of operation is another factor which possibly influences infection, and for this reason the surgeon might feel safer in closing these wounds primarily.

In this paper we shall attempt to evaluate the use of sulfonamides in compound-fracture wounds treated by primary suture, following débridement and careful irrigation of the wound. We have as the basis for this study two series of cases. In one series, treated from 1933 to 1941, no local or systemic drug was used, and this series will serve as a contrast. In the second series, from 1941 through 1943, one of the sulfonamide drugs was used locally, and in thirty cases was given by mouth postoperatively. It is our purpose to present these cases as comprehensively as possible in order that our series, admittedly not large, may be compared or added to other similar reports. We are limiting the scope of this report to the presence or absence of infection in the soft tissues or bone.

CASES FOR STUDY

This report is based on the records of 166 compound fractures occurring in 164 patients. The records of all compound fractures of the long bones, treated in the New Haven Hospital over a ten-year period, have been examined. Twenty-four of these patients have been omitted from this report, because either they died within a few hours of multiple injuries or shock, or they were treated by packing the wounds open. The only cases selected for this report were those treated by primary suture, following careful débridement and irrigation. Most of these injuries were sustained in automobile accidents, and the patients were brought to the Hospital by ambulance. The period elapsing between the initial injury and the time the patient arrived in the operating room varied from forty minutes to ten hours and forty minutes. One patient had a tiny wound that had been present twenty-four hours. The great majority of the patients, however, reached the operating room in from two to five hours following the accident. The ages of the patients varied from five to eighty-one years.

Table I shows the number and percentage of the various bones involved.

TREATMENT

All of these 164 patients were first admitted to the Emergency Room where they were seen by a doctor immediately. A general examination of the patient was then carried out, and, if shock was either present or impending, measures to control this were taken. The clothes about the wound were then removed and a sterile dressing applied. If the splinting done outside the hospital was not adequate, this was replaced. A prophylactic dose of tetanus antitoxin was given in all cases, and most of the patients received gas-bacillus

TABLE I
LOCATION OF FRACTURES

Bone	Number	Percentage of Total
Humerus	22	13.3
Radius	28	16.8
Ulna	16	9.6
Femur	2	1.2
Tibia	95	57.3
Fibula	3	1.8
Total	166	100.0

antitoxin in addition. After these measures had been completed, roentgenograms were taken, and the patient was sent directly to the operating room.

After satisfactory anaesthesia had been obtained, another sterile dressing was applied to the wound; the extremity was thoroughly cleaned and the dressing was removed. The surgeon then prepared the field about the wound. (During the past three years, soap, alcohol, and tincture of zephiran have been used. In the period before this, soap, benzine, ether, iodine, and alcohol were used.) The surgeon then discarded his gloves and draped the field in the usual manner as for a major procedure, and put on a sterile gown and gloves.

Following excision of the skin edges with a scalpel, thorough débridement and irrigation of the wound were done, from within outward. (Since 1941, it has been a routine procedure to put sulfathiazole powder or sterile sulfanilamide powder throughout the wound.) Closure of the wound was then carried out with interrupted catgut sutures in the deep tissues and silk in the skin. Postoperatively, a dry, sterile dressing has been kept on the wound, in recent years. In the period from 1933 to 1939, it was the practice of a few surgeons to place a tiny rubber drain at one end of the wound; this was removed at the end of twenty-four hours for culture. Some surgeons used alcohol dressings at that time.

Since the use of the sulfonamide drugs began in 1941, the drug has been given orally in many cases for about seven days postoperatively, or for a longer period of time if infection occurred in the wound.

The treatment of the fracture itself varied. In the earlier cases of this series, some fractures were treated with catgut or braided silk to approximate the bone ends. Since 1941, if some internal fixation was indicated, metal screws or plates have been used. Traction or casts have been used routinely as the surgeon deemed advisable in the individual case.

Wound Healing

Rather than dividing these 166 wounds into only two groups, it seemed more informative to place them in four groups, as follows:

1. Cases in which primary healing took place.
2. Cases where separation of skin edges, superficial skin necrosis, or small hematomata occurred.

These three complications of wound healing were difficult to fit into the infected group, because the wounds all healed within a few days or weeks by secondary intention without any definite signs of infection. Likewise, these wounds could not be considered healed by primary intention, even though the skin separation involved only a small portion of the wound.

3. Infected wounds.

This group is, of course, difficult to separate definitely from those cases with a mild osteomyelitis, but we have endeavored to put in this group only those cases in which the infection, as far as we could tell, was limited to the soft tissues.

These wounds all healed without sinus-tract formation or changes suggestive roent-

TABLE II

WOUNDS IN WHICH OSTEOMYELITIS DEVELOPED

Age	Injury	Fracture and Wound	Time to Operating Room	Treatment	Drug	Course	Condition of Wound on Last Visit to Hospital
60	Struck by auto	Tibia. Laceration of ten centimeters, with bone protruding.	Four hours	Irrigation, débridement, suture. Skin sutured under tension. Traction and cast.	None	Skin became necrotic about wound and sutures pulled through. Purulent drainage then began.	Sequestrum removed one year after injury. Wound healed four months later. No recurrence at two years.
20	Struck by auto	Tibia. Large wound with bone protruding.	Three hours, fifty minutes	Irrigation, débridement, suture. Dirty bone rongeured away. Tension sutures used. Traction and cast.	None	Tension sutures pulled through. Purulent drainage began.	Continued to drain pus through sinus for one and one-half years.
39	Struck by auto	Tibia. Large dirty wound.	Four hours	Irrigation, débridement, suture, traction.	None	Purulent drainage.	Drainage through sinus tracts over tibia for four months. Patient then left.
21	Struck by auto	Humerus. Wound four centimeters wide.	Four hours	Irrigation, débridement, suture. Braided silk in bone ends. Traction.	None	Sinus tracts formed. Silk removed from bone at nine weeks, but drainage continued.	A few small sequestra were extruded from time to time. Wound healed in seven months.
41	Struck by auto	Tibia. Large dirty wound containing gravel. Bone protruding.	Three hours	Irrigation, débridement, suture. Traction.	None	Wound infected. Progressive osteomyelitis developed. Amputation done four months after injury.	Stump healed after a period of two years from injury. Re-amputation required for healing.
62	Struck by auto	Tibia. Dirty wound of four inches. Bone protruding.	Two hours and a half	Irrigation, débridement, suture. Plate and cast.	Yes	Wound infected. Plate removed. Continued to drain pus.	Draining from sinus tracts after two years.
51	Struck by auto	Tibia. Large wound.	Six hours	Irrigation, débridement, suture with tension. Traction.	No	Infected and drained pus.	Draining pus from open wound at one and one-half years. One small piece of necrotic bone removed.
62	Struck by auto	Tibia. Dirty wound of eighteen inches.	Four hours	Irrigation, débridement, suture. Traction.	Yes	Infected. Skin sloughed. Bone exposed.	Drained one year, then stopped. Bone exposed. No recurrence after six months. Died of coronary thrombosis.
19	Fall in street	Tibia. Puncture wound by sharp object.	Four hours, fifteen minutes	Irrigation, débridement, suture. Traction.	None	Infected. Wound opened and drained profusely.	Extruding small fragments of bone at nine months.

TABLE III
COMPARISON OF WOUND HEALING IN COMPOUND FRACTURES

	Sulfonamide Therapy		No Sulfonamide Therapy	
	Number	*Per cent.*	*Number*	*Per cent.*
Primary healing	30	71.5	82	66.2
Skin necrosis, separation of skin edges, or hematoma	4	9.5	18	14.5
Soft-tissue infection	6	14.3	17	13.7
Osteomyelitis	2	4.7	7	5.6
Number of compound fractures	42		124	
Total of infected wounds	8	19.0	24	19.3

genographically of osteomyelitis, and consequently are considered merely soft-tissue infections.

4. Infected wounds with osteomyelitis.

In this group are the wounds from which sequestra were extruded or removed, which had a persistent sinus tract leading down to the bone, or which showed by x-ray changes consistent with osteomyelitis. Table II lists these patients. This table is presented to demonstrate the importance of the size and character of the wound in relation to the infection of the bone.

Table III is a tabulation of the wound healing in the two series of cases.

Incidence of Infection

In order to make this report as accurate as possible, we have endeavored to list and compare most of the important factors, other than the use of the drug, which have some effect on the incidence of infection in these wounds. Three of the factors are listed in Table IV. The character of the initial surgical treatment of the wound is more difficult to control accurately. However, all of these cases were treated by a routine method. The surgeons were either of a small group of attending men, or were Residents in Orthopaedic Surgery, working under the supervision of one of the faculty. The time elapsing between injury and arrival in the operating room was in most cases from two to five hours, with no significant variation in the two series. Finally, the amount of tension under which the wound was closed, a factor of recognized importance in production of infection, is not recorded in most of the notes; so we have not attempted to evaluate this factor.

TABLE IV
FACTORS FAVORING WOUND INFECTION IN THE TWO SERIES OF CASES

	No Local or General Sulfonamide		Local Sulfonamide	
	Number	*Per cent.*	*Number*	*Per cent.*
*Large wound	58	46.7	22	52.4
Grossly dirty wound	14	11.3	8	19.0
Bone protruding through skin	11	8.8	9	21.4

* Any wound over one inch in diameter or length

Infection occurred in eight (19 per cent.) of the forty-two cases in our series, treated with the drug; this is almost the same percentage as in the series of Baker. In his report of 252 fresh compound fractures, treated with local sufonamides and primary suture, there were forty-seven infections, or about 18.6 per cent.

Two conflicting reports comparing wound healing with and without the use of sulfonamides have appeared in the literature. Jensen and Nelson report infection in 27 per cent. of the compound-fracture wounds treated without the drug. In their cases in which

the drug was used, only 3.3 per cent. were infected. Not all of their cases were treated by primary closure.

Meleney, on the other hand, after studying a large group of these wounds, concluded, "The combined local and general, or the general, use of sulfonamides alone have not lowered the incidence of local infection".

SUMMARY

1. The records of 166 compound fractures occurring in the long bones have been studied.

2. All of these fractures were treated by primary suture, following débridement and irrigation. Forty-two of the total number had one of the sulfonamides applied locally in the wound, and thirty of these received systemic treatment in addition.

3. Definite infection occurred in 19.3 per cent. of the wounds treated without the drug. Infection developed in 19.0 per cent. of the wounds in which the sulfonamide drug was implanted.

4. We have not attempted to classify the infections as trivial or serious. However, the percentage of serious infection, as evidenced by osteomyelitis, was about the same in the two series.

5. We cannot show that the local use of sulfonamide in these cases altered the incidence of infection.

6. In our two series of cases, early and careful débridement and irrigation were apparently the most important factors in preventing infection.

NOTE: The author wishes to express his appreciation to Dr. Samuel C. Harvey and Dr. John S. Lockwood for their excellent suggestions in the preparation of this paper.

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TUBERCULOSIS OF THE SPINE

A Case Report

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Recovery from tuberculosis of the spine, following extensive fusion, may be so complete as to cause a watchful Pathology Service to upbraid an active Orthopaedic Service for having performed spine fusion on an assumed diagnosis of tuberculosis of the spine, some years before the patient's death. In the following case, recovery had occurred to such an extent that the Pathology Service notified the Orthopaedic Service that on autopsy absolutely no evidence of tuberculosis of the spine could be found five years following fusion. The pathologists questioned the necessity of such a procedure. This query was startling, and the following case report is presented so that the reader may decide for himself.

The patient was a Puerto Rican, thirty-three years old, when referred from another hospital in New York City in May 1938. Thoracentesis of the right chest was done, yielding 100 cubic centimeters of yellow pus. Rib resection on the right was carried out, and a large, paravertebral abscess was found, which upon evacuation proved to be tuberculous. The patient was transferred to Sea View Hospital.

At Sea View Hospital, he was found to have a draining sinus over the previously resected right ribs (seventh and eighth), with a slightly narrow disc space between these segments of the spine, and a

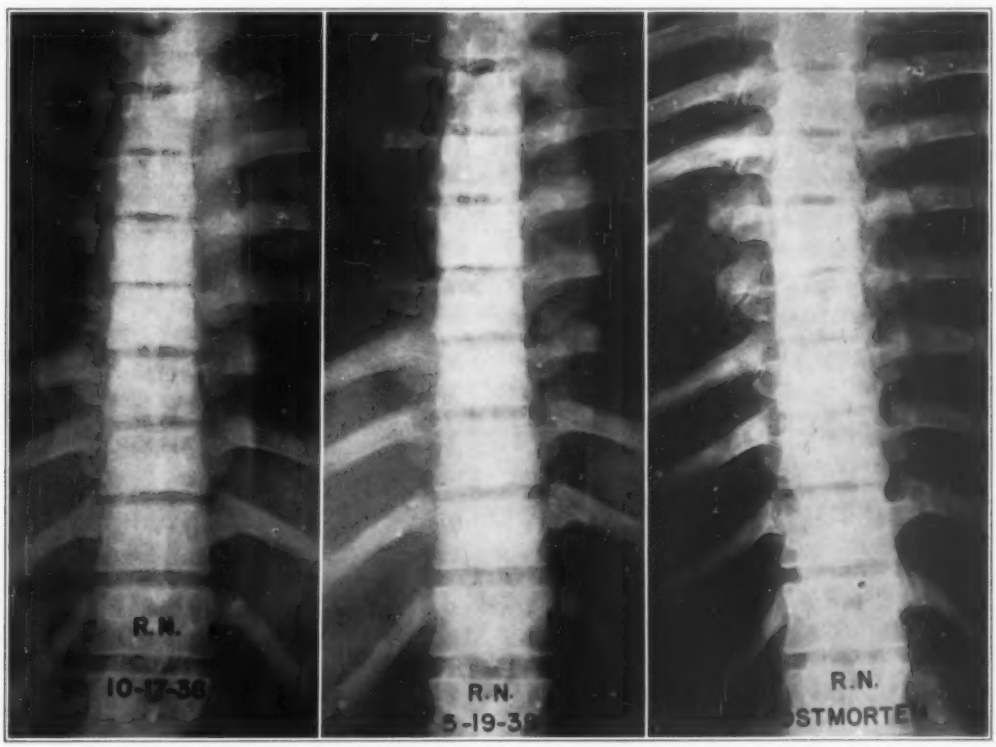

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: R. N. Paravertebral shadow of third to twelfth thoracic vertebrae with slight narrowing of the disc of the seventh thoracic vertebra.

Fig. 1-B: Shadow of the paravertebral abscess has decreased in the seven months following spine fusion.

Fig. 1-C: X-ray just before autopsy. Five years since Fig. 1-B.

FIG. 2

Gross specimen of spine split showing slight narrowing of the disc of the seventh thoracic vertebra with apparent vacuolation of center. Roentgenogram shows some calcification of the disc of the seventh thoracic vertebra without gross involvement of the vertebrae elsewhere.

FIG. 3

Photomicrograph showing concentric area composed of hyalinized connective tissue surrounded by loose connective tissue. No other such areas were found. This is a tiny residual for such massive previous involvement.

massive soft-tissue paravertebral shadow, extending from the third to the twelfth thoracic vertebra. A diagnosis was made of tuberculosis of the spine with probable involvement throughout the extent of the abscess. A left hemi-spine fusion was performed in November 1938, and shortly thereafter the right side was fused, the fusion being extended upward to include the sixth cervical vertebra. On gross examination, at the operative procedures, the posterior elements of the spine were found to be free of disease. Solid ankylosis of the spine was secured. The rib sinus healed; the patient's general condition improved; and he became ambulatory, although he remained under observation.

Because of continuous low cervical pain, but without evidence of involvement of the cervical spine, fusion was extended upward in October 1943 to include the third cervical vertebra. Subsequently the patient developed a right hemiplegia which resulted in death in March 1944.

An unusually careful and extensive autopsy showed some fibrosis of the paravertebral tissue throughout the cervical and thoracic regions. Of the many sections made about the seventh and eighth thoracic vertebrae and the intervening disc, only one showed abnormality, consisting of "a concentric area composed of hyalinized connective tissue surrounded by loose connective tissue". Grossly, the disc of the seventh cervical vertebra appeared slightly narrowed, with a somewhat vacuolated appearance. There was no evidence of tuberculosis grossly or microscopically.

The presence of a paravertebral abscess in the thoracic region is the earliest criterion for diagnosis of tuberculosis of the spine, far antedating bony or interspace changes. At Sea View, we accept such criteria as diagnostic, and proceed with fusion to cover the involved area. Therefore, it is important to realize that complete recovery from a pathological as well as a clinical standpoint may occur, as in the present case where there had previously been what the author considers to be absolute proof of tuberculosis.

The patient's death was apparently due to multiple emboli and infarctions which were found to involve the lung and the kidney, and presumably the brain. Bronchopneumonia was a terminal finding. The source of the emboli was atherosclerosis of the aorta with ulceration.

EPIPHYSITIS OF THE ISCHIAL TUBEROSITY

A Case Report *

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Failure of bony fusion of the secondary epiphysis of the ischial tuberosity with fragmentation, resulting in painful disability, is a rare occurrence, and no report of such a condition was found in the literature. Therefore, having encountered such an unusual case, it seemed that a report might be of interest.

The patient, white male, nineteen years old, was a Private First Class in the Marine Corps. He was admitted to the Hospital September 17, 1944, complaining of pain in the left buttock and limb. He gave a history of having first experienced pain when, at the age of fourteen, while running, he jumped down an incline of a few feet and landed on his left foot. Immediately he had such severe pain in the left buttock that he fell. Pain was so extreme that he was unable to get up, and had to be taken home in the car of a passing motorist. The patient spent nearly four months in bed, getting up only occasionally. Toward the end of this period, with assistance, some weight-bearing was possible.

For several weeks thereafter he walked with a limp and required the aid of a cane. Gradually the pain which was "deep in the left buttock" decreased. At this time, the patient saw a doctor, and roentgenograms were made, which showed a "chip off the left hip bone".

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FIG. 1

Anteroposterior roentgenogram of pelvis, showing failure of bony fusion of an enlarged and fragmented secondary epiphysis of the left ischial tuberosity. Irregularity in outline and density of the apposing bony surfaces and the intervening cartilaginous plate is noted.

Approximately a year later, he was able to play baseball and football. However, at various times while engaged in athletics pain in the left buttock and limb occurred, which did not confine him to bed, but kept him out of athletics for a few days. Rest, heat, liniment, and massage gave sufficient relief so that he was able to resume the sport.

In the Spring of 1943 the patient played on the varsity baseball team of a large southern university, and had no significant recurrence of his trouble. He joined the Marine Corps in July 1943, and went through boot camp training as well as "staging operations" with only an occasional flare-up of pain, but he did not report to sick bay. He had been with the initial invading force at Guam, and on his twelfth day of fighting, August 2, 1944, he received a superficial bullet wound of the right arm, and jumped into a foxhole, landing on his buttock. He immediately had severe pain in the left buttock, similar to all the previous attacks. He was unable to move and morphine was required to control the pain. Soon thereafter he was moved by stretcher to a boat, then to a ship, and was evacuated through two mobile hospitals before arrival at this Base Hospital.

Physical examination revealed a well developed white male, nineteen years of age. The superficial bullet wound of the right upper arm was nearly healed and causing no trouble. With difficulty the patient got out of bed and walked, having a marked left limp. He stood with left knee and hip flexed, bearing weight on the right. There was moderate bilateral lumbar muscle spasm with limited spinal motions approximately 75 per cent. of normal in all directions. These motions, especially forced flexion, caused pain in the left buttock and limb. There was tenderness over both the sacro-iliac and lumbosacral areas, as well as of the lower sacrospinalis muscle groups.

Marked tenderness was present on deep palpation over the left ischial tuberosity, which was noticeably larger than the right. No mobility of the epiphysis was demonstrable. At rectal examination, tenderness of the left perineal floor and lower left sacro-iliac region was noted.

The limbs were of equal length, but the left mid-thigh revealed one inch of atrophy and the calf one-half inch, compared to corresponding points of the right. Motion of both hips, particularly of the left, was limited and, when forced, caused pain in the left ischial area. All other joint motions of the lower extremity were normal. Straight-leg raising was limited to 70 degrees on the right and 55 de-

grees on the left. Stretching of left hamstring muscles was very painful. Lasègue's sign was negative bilaterally. Reflexes and sensations revealed no abnormal findings.

Roentgenographic study revealed failure of bony fusion of a large irregular fragmented secondary epiphysis of the left ischial tuberosity. Apposing bony surfaces were irregular in outline and density, and the intervening cartilaginous plate showed some irregular density suggestive of attempt at bony fusion. (See Figure 1.)

Urinalysis, red and white blood-cell counts, and hemoglobin were normal. A smear was negative for malaria, and the Wassermann test was negative.

After eight weeks of bed rest with daily heat, liniment, and diathermy, moderate improvement was noted, but the patient was evacuated to the United States as unfit for strenuous field and combat duty.

DISCUSSION

The secondary epiphysis for the ischial tuberosity appears at the age of puberty, and unites at twenty to twenty-five years of age, according to Cunningham.

Although the patient was nineteen years of age, when union of the epiphysis could not yet be expected to be complete, there was no indication that the epiphysis was fusing with the diaphysis. The opposite ischium was normal in appearance, and revealed fusion of its secondary epiphysis. Thus it is assumed that the fragmented ununited epiphysis of the involved side will persist, possibly giving rise to recurrent pain in the event of either direct or indirect trauma.

The treatment recommended for this patient was rest, heat, and salicylates for the control of acute exacerbations. He was also advised to refrain from too strenuous physical activity. Surgical intervention did not appear indicated as the patient had always previously recovered from his recurrent attacks, and was improving from this one.

There is no uniformity of opinion as to whether an ununited, fragmented, painful secondary epiphysis should be designated "epiphysitis", "osteochondritis", or "osteochondrosis", as suggested by Harbin. "Strain" was suggested by Watson-Jones for the condition.

A careful review of this patient's history indicates that, at the age of fourteen, indirect trauma with an avulsive type of strain of the secondary epiphysis of the left ischial tuberosity had precipitated his trouble. Thereafter repeated indirect traumata, with an occasional direct trauma, kept the condition aggravated. There was no evidence, either in the history or examination, of any endocrine disturbance or other epiphyseal lesions. The patient was unaware of any similar bone lesion in members of his family. There was no history of any serious systemic disease.

It appears then that this patient's condition is primarily of traumatic origin. Clinical and roentgenographic features are similar to the involvement with subsequent failure of bony fusion of the epiphysis of the tibial tubercle, described by Osgood and Schlatter. Although epiphysitis of the ischial tuberosity suggests an inflammatory or disease process, such a factor evidently did not exist in this case, as trauma seemed to be the main etiological factor. However, as the secondary epiphysis and associated cartilaginous plate of the ischial tuberosity were involved, and since definite pathological changes were present by roentgenographic study, the term "epiphysitis" is used to describe this condition, and is considered to be descriptive in view of our present knowledge of the pathogenesis of such lesions.

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A SIMPLIFIED SURGICAL APPROACH TO THE POSTERIOR TIBIA FOR BONE-GRAFTING AND FIBULAR TRANSFERENCE

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The increasing number of osseous reconstructions of the leg present various problems, and it becomes more and more important that the surgeon have at his command a wide variety of approaches. The writer has been using for several years a simple posterolateral approach to the tibia. This approach is useful in bone-grafting from the posterior aspect, in cases of minor residual infection or extensive scarring of the anterior aspect of the leg. It has also been used for fibular transference, an operation gaining in usefulness as a remedy for extensive loss of bone from the tibia. Priority is not claimed for this method, which probably has been used sporadically by many surgeons, but this simple surgical approach is described in the hope that it will be of aid to others.

SURGICAL TECHNIQUE

The operation is carried out with the patient lying prone or in the posterior oblique position. The lower extremity is prepared in the usual manner for bone surgery. The skin incision extends along the lateral border of the gastrocnemius and soleus on the posterolateral aspect of the leg. Its extent varies with the size of the operative field desired. For exposure of the middle three fifths of the tibia and interosseous membrane, the field which is most easily made available, the skin incision extends inferiorly almost to the lateral malleolus (Fig. 1).

The plane of division between the soleus and the flexor hallucis longus is identified as well as the peroneus longus and brevis, which lie anteriorly and form the floor of the field when the leg is opened. Reflection of the soleus and the flexor hallucis longus is then made to the medial side. This bares the posterior face of the fibula, which is the landmark for orientation in this approach. Deep retractors are inserted to pull the posterior muscle mass medially. As this is done, the tibialis posterior is dissected in part from its origin on the posterior aspect of the interosseous membrane. As this latter separation proceeds, the posterior muscle mass falls to the medial posterior side of the leg with greater ease. The only vessels or structures of even minor importance which are encountered in this approach are the muscular branches of the peroneal artery, seen high in the wound in association with the peroneal muscles. It is to be noted that the posterior tibial artery, vein, and nerve are not exposed, and are retracted medially in the muscle mass, since they lie between the tibialis posterior and the flexor hallucis longus.

The dissection at this stage is seen in Figure 2. The posterior half of the fibula is prominent in the lateral border of the wound. The entire fibular shaft, with the exception of the fibular head and the lateral malleolus, can be easily explored by subperiosteal dissection. Practically no bleeding is encountered, inasmuch as the deep dissection is concerned chiefly with the separation of the fibers of origin of the tibialis posterior from the interosseous membrane. The flat posterior surface of the tibia is exposed in its entirety, except for its upper fifth, which is in intimate relation to the popliteus muscle and the first portion of the posterior tibial vessels and nerves. Because of these latter structures, the posterior approach is undesirable for exposure of the tibial condyles. The surgeon should note that the flat posterior aspect of the tibial shaft is an excellent surface from which to cut reversible grafts, and for the application of onlay bone grafts. Room is available for the operation of the motor-driven saw when adequate retraction of the

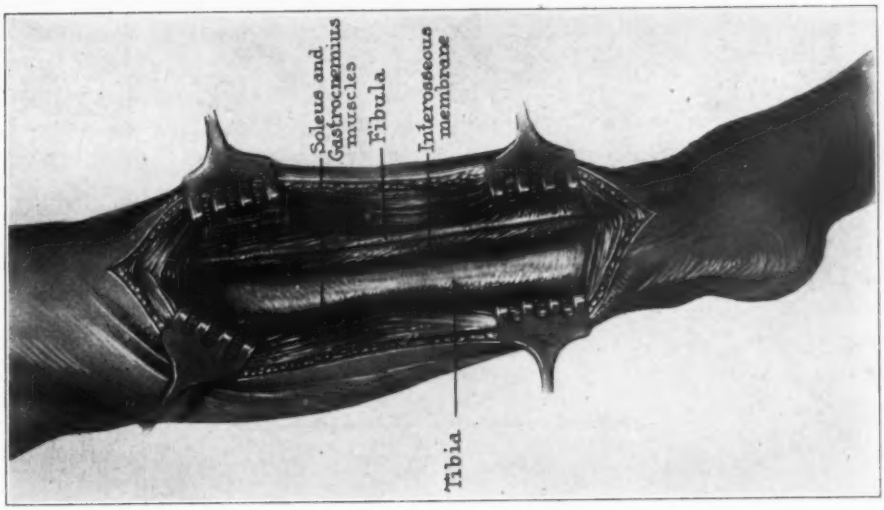

FIG. 3

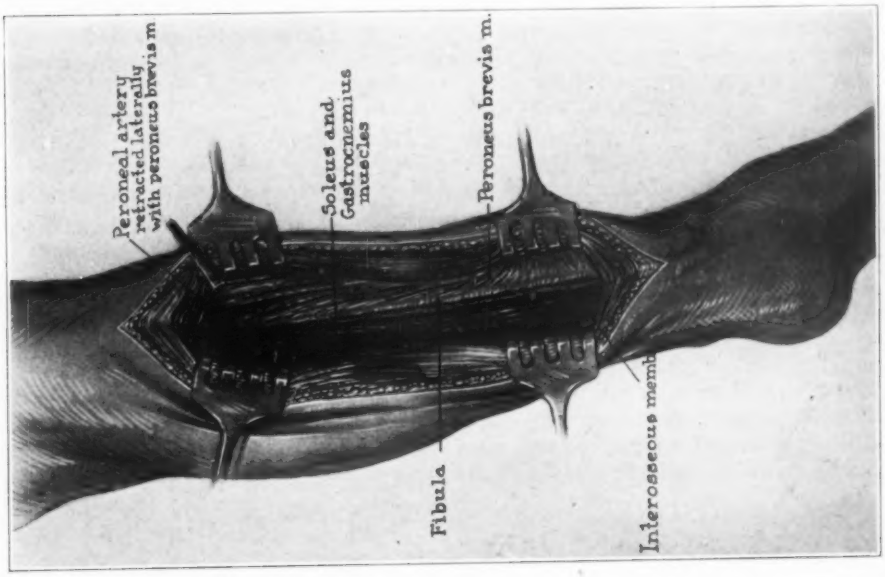

FIG. 2

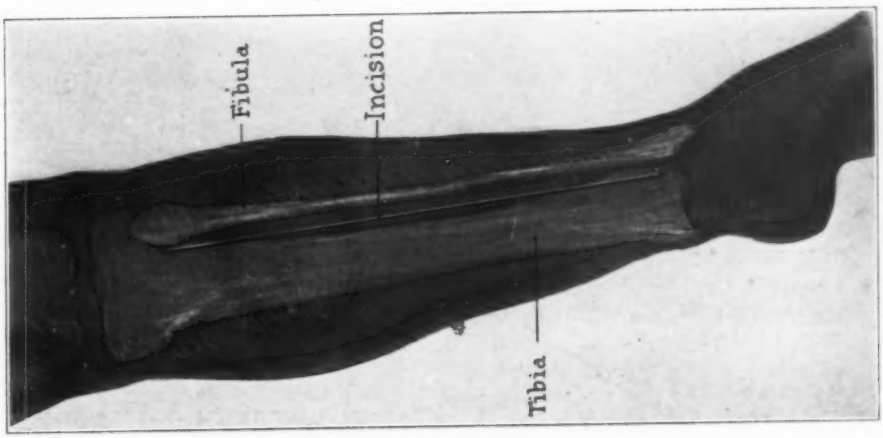

FIG. 1

posterior muscle mass has been secured. For the synostosis operation, the appropriate procedures can be carried out with a full view of all structures. The exposure in the depths of the wound is shown in Figure 3.

At the termination of the operation, immediate release of the retractors permits the posterior muscle mass to resume its normal place. In the closure, it is necessary only to unite the deep fascia on the lateral side of the leg with a few interrupted stitches, and subsequently to close the skin. There is no danger of skin necrosis, as the skin of this portion of the leg is pliable, and there are many thicknesses of muscle between the skin and any bone which may have been added. The author has never observed circulatory difficulties or difficulties in healing of the wound, following the use of this approach.

FRACTURE-DISLOCATION OF THE BASE OF THE FIFTH METACARPAL

A Case Report

BY CAPTAIN BAXTER L. CLEMENT

Medical Corps, Army of the United States

Isolated dislocations of the base of the fifth metacarpal are rare, and have been reported infrequently. A review of the literature reveals that McWhorter reported one case in 1918, stating that he had been unable to find any record of a previous case. Roberts and Holland of the Liverpool Royal Infirmary reported four cases in 1936.

CASE REPORT

Sergeant F. R., white male, twenty-four years old, was admitted to the Station Hospital on May 23, 1944, complaining of severe pain and deformity of the right hand. He gave a history of striking the dorsum of the hand, over the fifth metacarpal, on the edge of a table, while scuffling with a fellow soldier.

With the exception of the injured hand, physical examination was negative. There were no marks or bruises on the hand. There was moderate swelling over the base of the fifth metacarpal on the dorsal aspect. The outstanding objective findings were modified claw position of the hand, complete loss of knuckle of the fifth metacarpal, ulnar deviation of the little finger, and inability to approximate the little finger to the ring finger. There was a minimum of local reaction, and the first clinical impression was that the deformity might have been the result of an old injury. A photograph (Fig. 1) of both hands was taken for comparison, which illustrates the deformity. Roentgenogram of both hands, also taken for comparison, revealed a dorsal dislocation of the base of the right fifth metacarpal on the carpal hamate. It also showed a minor fracture of the base of the metacarpal on the radial surface. There was slight shortening of the metacarpal.

FIG. 1

Photograph of both hands illustrates the deformity of the right hand, and cupped position of hand. There is absence of knuckle to little finger, and ulnar deviation of the finger.

The patient was given sodium pentothal intravenously, and, with traction on the little finger, together with pressure over the base of the fifth metacarpal from the dorsal surface, reduction was comparatively easy, but occurred

FIG. 2

Roentgenogram reveals fracture-dislocation of the base of the right fifth metacarpal on the carpal hamate.

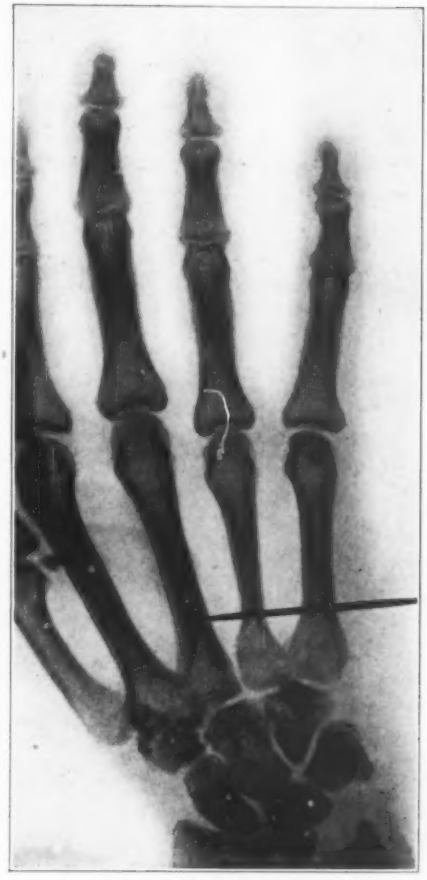

FIG. 3

Postreduction roentgenogram shows reduction and fixation with Kirschner wire.

with a crunching sound which could be heard across the operating room. The reduction could not be maintained, and the dislocation recurred with the slightest manipulation of the finger. (This same finding was noted by Roberts and Holland.) It was felt that the dislocation could not be maintained with plaster-of-Paris; therefore, a Kirschner wire was inserted in the proximal third of the metacarpals to the little, ring, and middle fingers. After this, no amount of manipulation of the fingers or hand caused a recurrence of the dislocation. The visible deformity of the hand had been corrected by reduction. The knuckle had been re-established, the claw position of the hand had disappeared, and the little finger had resumed a normal position.

Figure 3 reveals the complete reduction obtained. The joint space between the base of the fifth metacarpal and the hamate has been re-established, and appears to be normal.

The soldier returned to duty three days after the injury. On removal of the wire, four weeks after insertion, he had normal, painless motion of the fingers and wrist.

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CHRONIC DISLOCATION OF THE BASE OF THE METACARPAL OF THE THUMB

BY G. W. N. EGGERS, M.D., GALVESTON, TEXAS

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Chronic dislocation of the base of the metacarpal of the thumb offers a functional problem of importance. Movement is impaired rather than lost; and, therefore, the partial disability is often endured. Correction demands stability and retention in reduction,

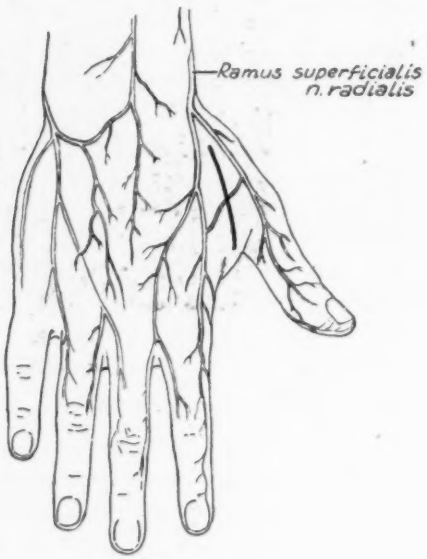

FIG. 1-A
Location of skin incision.

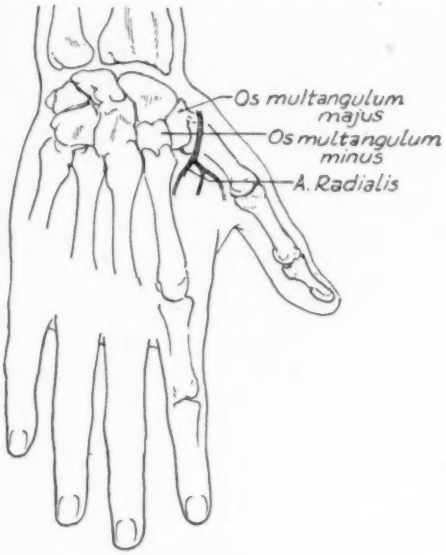

FIG. 1-B
Showing branch of radial artery in the operative field.

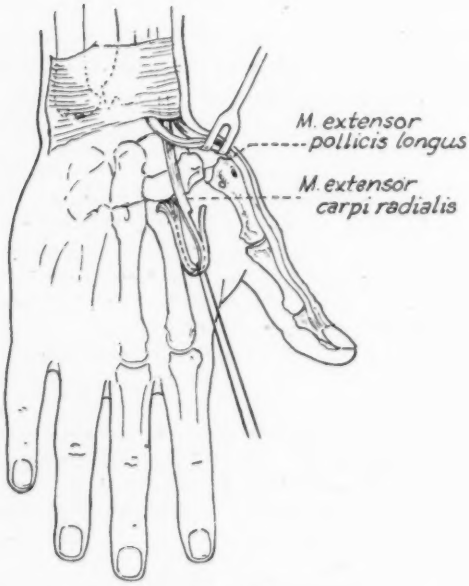

FIG. 1-C
Method of splitting the tendon of the extensor carpi radialis longus.

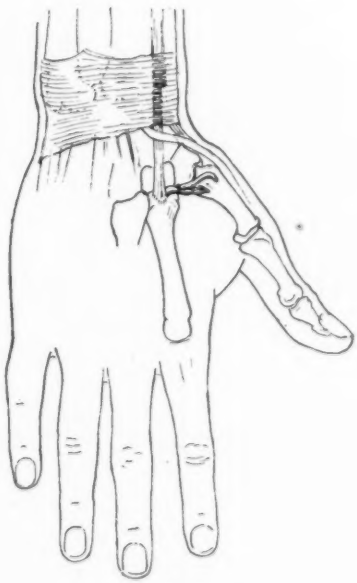

FIG. 1-D
Retention of reduction of the dislocation.

as adduction and opposition are performed. The surgical procedure described has been found to meet functional requirements.

The incision is made on the dorsum of the hand, extending from between the metacarpal of the thumb and that of the index finger to a point proximal to the articulation of the first metacarpal and the greater multangular (Fig. 1-A). It is important to preserve the digital sensory nerves, and these should be seen and retracted. The next step is to identify and ligate the branch of the radial artery perforating the interphalangeal space. This vessel varies in size (Fig. 1-B). The metacarpal is liberated at the base, and the fibrous tissue is removed. (Seldom is it necessary to liberate metacarpal portions of the adductor of the thumb.) The dislocation can then be reduced. The correction of the dislocated metacarpal, which is not easily maintained, is accomplished by utilizing the tendon of the extensor carpi radialis longus. This tendon, inserted into the base of the metacarpal of the index finger, is in two portions,—medial and lateral. The tendon is drawn down from its sheath, and the lateral portion is divided to secure a band (Fig. 1-C). The tendon is released, and the divided band is inserted into the metacarpal of the thumb through holes drilled near the base (Fig. 1-D). It is important that the insertion be near the articular surface for proper retention during adduction and opposition. The tendinous slip is made taut, and is sutured into position with silk. After the usual skin closure, a plaster cast is applied, with the thumb in a position of anatomical rest, and the correction is maintained for three weeks. Return of function is satisfactory.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Chronic dislocation of the base of the metacarpal of the thumb, before correction.

Fig. 2-B: Chronic dislocation of the base of the metacarpal of the thumb, after correction.

CASE REPORT

J. B., forty years of age, was a café proprietor. During the first week of January, 1944, the patient was lifting a "side of beef" which slipped. As it fell, his thumb was caught so as to bear the weight of the beef. There was a severe pain in his right thumb, and he could feel it "slip out of joint". Swelling of the part followed, and he sought the advice of his family physician who reduced the dislocation of the thumb, and applied adhesive to retain the reduction. The diagnosis, made from a roentgenographic study, was complete dislocation of the base of the metacarpal of the right thumb from the greater multangular.

The reduction was not satisfactory, and a splint was applied to the thumb. This method also failed, and a plaster cast was applied. Two weeks later the cast was removed, and the dislocation of the right thumb recurred.

The dislocation could be corrected easily, and the patient would do so at his own pleasure. Retention of the first metacarpal in the normal position was not possible, for redislocation would immediately take place. This condition was quite annoying, because of the instability of the thumb and the pain present when he was working. He was right-handed, which made the condition a handicap to his working efficiency.

On February 4, 1944, the patient was examined, and an open reduction was performed by means of the operative technique described. Anaesthesia was by local infiltration.

Four weeks after operation, the patient had returned to his usual work. The function of the thumb was satisfactory, and was not painful. An examination ten months later revealed that the metacarpal of the thumb had remained in the corrected position and dislocation had at no time recurred.

COMPOUND WOUND OF THE KNEE JOINT WITH RETENTION OF SEA SHELLS AND BEACH SAND

A Case Report

BY WILLIAM E. KENNEY, M.D., NEW HAVEN, CONNECTICUT

From the Section of Orthopaedics, Department of Surgery, Yale University School of Medicine, and the New Haven Hospital, New Haven

The physician is occasionally required to treat a single case which presents a multitude of complex problems. Sometimes there is no adequate precedent upon which he can base his decisions. Nevertheless, he regards it as a profitable experience, and feels justified in reporting it and discussing it in some detail. The patient, whose case is herein reported, suffered from a laceration of the quadriceps extensor femoris tendon, a compound wound of the knee joint, the retention of two types of foreign bodies within the knee (one of which was submeniscal in location), and suppurative arthritis. The problems were dealt with in such a way that the patient now has a satisfactorily functioning knee joint.

CASE REPORT

W. B., a white male, sixteen years of age, appeared in the Emergency Room of the New Haven Hospital on August 1, 1943, with the complaint of a cut on his left knee.

About two and one-half hours before admission the patient had run down a sloping beach, and had dived into the water where he struck protruding rocks with his left knee. He was immediately unable either to walk or to swim.

Examination revealed a laceration five centimeters long, located one and one-half to two centimeters above the superior border of the left patella. In the depths of the laceration the cut edges of the quadriceps tendon could be seen, as well as the anterior aspect of the femur. There was total inability to extend the leg.

Roentgenograms showed no evidence of fracture, but in the lateral view there was a small and faint calcific shadow situated behind the femoral condyles. This was absent in the anteroposterior projection.

Therefore, the clinical impressions were laceration of the quadriceps tendon and compound wound of the knee. The patient was taken to the operating room where débridement of the superficial tissue down to the tendon was carried out. The wound was copiously irrigated with saline, and a suspension of sulfathiazole was placed in the joint. No foreign objects were noted. The suprapatellar bursa was sutured by interrupted silk, as were also the tendon and its lateral expansion. The wound was closed without drainage, and a cast was applied with the leg in extension. The patient was given tetanus antitoxin and was placed on sulfadiazine systemically. On the tenth postoperative day, the wound was clean and healed.

Ten and one-half weeks after the injury, the cast was removed, and physiotherapy was started.

About three months after the original injury, a roentgenogram was made because of incidental trauma to the left knee. This revealed that the calcific shadow noted previously was now definitely within the posteromedial compartment of the joint.

An upper respiratory infection developed on December 2, 1943, and nine days later, the left knee suddenly became swollen, painful, tender, and hot. The temperature was 101.6 degrees, and the general physical examination was negative. Aspiration of the left knee yielded seventy-five cubic centimeters of yellow cloudy fluid (not purulent) on which a cell count was 121,000 per cubic millimeter, 92 per cent. of which were polymorphonuclear leukocytes. The smear showed gram-positive cocci in chains, although both the blood culture and fluid culture were sterile. Repeated aspirations, cultured both aerobically and anaerobically, yielded no growth of organisms. The patient's temperature gradually fell to normal on the fifth day.

Following this episode the knee remained swollen and had a boggy consistency to the touch, not unlike that of chronic synovitis. Flexion was possible to 70 degrees (complete extension being 180 degrees).

The patient returned to the Hospital on February 11, 1944, with the statement that, while walking the night before, he had noticed a "soft" but "not bony" resistance to flexion deep within the knee. A few hours thereafter the joint had become painful and swollen. The temperature was 100.8 degrees. Aspiration yielded a cloudy fluid, which was negative to culture, and smears showed no organisms.

Further roentgenograms revealed that the "joint mouse" had been broken up into three pieces. Therefore, the patient was admitted for arthrotomy on February 16, 1944.

OPERATIVE PROCEDURE

The region of the left knee was prepared and draped routinely. A posteromedial approach to the posterior compartment was used. The tibial collateral ligament was divided vertically at the junction between the oblique and straight portions. The synovial membrane of the posterior compartment was incised, and a moderate amount of synovial fluid escaped, which contained what appeared to be beach sand. Irrigation, the introduction of gauze tips, and digital exploration all failed to produce the foreign bodies, and although it became possible for the operator to visualize the entire posteromedial compartment, nothing came into view. Roentgenograms taken at this time, however, showed that the three radiopaque calcific bodies were still present, apparently in the posteromedial compartment. It was then realized that the floor of the compartment was on a level with the superior aspect of the posterior horn of the medial meniscus. Furthermore, it seemed from the roentgenogram that the level of the foreign bodies was more nearly that of the superior surface of the tibial plateau or, in other words, underneath the medial meniscus. Accordingly, the posterior horn was dissected free, and the space between the tibial plateau and the medial meniscus was opened. This, for want of a better term, might be called the submeniscal compartment.

At this point, the two smaller objects became visible, and appeared to be pieces of a sea shell. It was not until the meniscus was lifted up, however, that the third and largest piece of the sea shell was found embedded in the inferior aspect of the meniscus. The largest measured three-sixteenths of an inch (0.5 centimeter) in its greatest diameter, and each of the two smaller measured one-sixteenth of an inch in its greatest diameter. After irrigation the wound was closed with an interrupted silk technique.

Within less than twenty-four hours after the skin closure, the temperature had already reached 103 degrees. The patient became violently ill with a temperature reaching to 103.2 degrees daily, a pulse of 120 to 140, and respirations of 35 to 40. The general physical examination (including that of the lungs) was negative. Culture of the wound was sterile, and the blood culture was negative. The knee was aspirated of purulent material which yielded a hemolytic staphylococcus aureus. This organism fermented mannite and was coagulase positive.

The joint was aspirated and irrigated with saline through the aspiration needle for fifteen minutes, and 5,000 units of penicillin were injected into the joint daily. This was followed twenty-four hours later by another irrigation and more penicillin. Such treatment was continued for five days. At this point the irrigation was discontinued, and 10,000 units of penicillin were injected into the knee joint every other day for two weeks.

On the tenth postoperative day, the leg was placed in skin traction of about five pounds on a Thomas splint with a Pearson drop. The splint was so arranged that the patient himself could give the knee passive motion in traction through 90 degrees of flexion to complete extension. Discharge to the Clinic took place four weeks after admission to the Hospital.

At present the patient has volunteered the information that "the sense of deep heat inside the knee" has gone. There is no effusion. Extension is complete, and flexion is possible to 60 degrees from 180 degrees, and is still improving. There is no relaxation of the knee, either in an anteroposterior or in a lateral direction. The knee is painless. The patient walks without a limp, can go up and down stairs without difficulty, and plays easily at strenuous sports, such as baseball and handball.

DISCUSSION

Only one case of a laceration of the quadriceps tendon[6] has been found in the literature, but there are at least seventy-seven cases of rupture of the quadriceps tendon reported. From these it can be gathered that suture of the tendon and immobilization in a cast for from two to six weeks is the preferred method of treatment. The choice of the length of time the leg is immobilized should be guided by what is known in regard to the rate of tendon healing, the forces it must withstand, and the function expected of it. Mason and Allen have pointed out several features, valuable to the intelligent management of a sutured tendon. According to their findings, it would seem that a lacerated tendon should be immobilized for three weeks, and then function should be started gradually.

However, it should be remembered that the quadriceps muscle has a large heavy tendon, and that the stresses put upon it are probably greater than those upon any other tendon in the body. Consequently, it is probably best to immobilize lacerations of the

quadriceps tendon for from six to eight weeks. The period of ten and one-half weeks in the case reported here is perhaps needlessly long.

A feature of cases of knee injury which has been emphasized constantly is the surprisingly profound and rapid atrophy of the quadriceps muscle. Measures to maintain the muscle in good condition, such as massage, stimulation, and quadriceps-setting exercises, have been advised and followed. However, relatively few authors[1,2,5,21] have pointed out the importance of the extensor apparatus to knee flexion. In the present case, postoperative flexion was limited to 95 degrees. The patient complained of a subjective feeling of resistance anteriorly overlying the region of the musculotendinous junction, upon attempting active flexion. Objectively, passive flexion of the knee was suddenly limited at the time when the quadriceps bellies were felt to become taut, firm, unyielding bands not unlike fibrous tissue to the touch. The limitation was not due to adhesions in the suprapatellar bursa. During the course of physical therapy aimed at stretching the quadriceps, the consistency of the muscle approached normal, and the flexion improved. It is urged that in cases showing limitation of flexion at the knee, this point be kept in mind, and treatment directed specifically to stretching the extensor apparatus.

Foreign bodies within the knee may be derived from two main sources, those introduced from without (exogenous foreign bodies) and the chondro-osseous bodies arising within the joint (which might be termed endogenous).

The common sites for endogenous bodies are the suprapatellar bursa, the anterior compartment, the medial aspect of the lateral femoral condyle, and occasionally the posterolateral compartment.

Mention has been made in the literature of various exogenous bodies,—needles, glass, wood, metal, and bullets. However, the combination of sea shells and sand is unique. The position of the shells was likewise interesting. Geist[12] reported a case of a chondro-osseous body under the lateral meniscus anteriorly. In 1929, the same author reported a second similar case of a loose body in the same obscure location, beneath the anterior horn of the lateral meniscus. In his series of 150 operations upon the knee, this position had occurred twice. Upon cadavera Geist found that there was adequate room under the lateral meniscus to hide a penny or a button. In 1928, Bizarro reported a case in which a fragment of glass was removed from underneath the posterior horn of the lateral meniscus.

It will be noted that the present case represents the first, so far as the writer has been able to determine, in which the foreign object was beneath the *medial* meniscus.

Geist and Bizarro point out, and it was adequately confirmed in this case, that operators usually are not fully conscious of the possibility that foreign bodies can be situated in the submeniscal compartments, either anteriorly or posteriorly. Therefore, it should be emphasized. The small size of the objects in this case did not reduce the difficulties for the operator, and yet, due to their peculiar and strategic position, they caused a severe and recurrent internal derangement. By lifting up the posterior horn of the medial meniscus, they were probably responsible for the patient's complaint that flexion of the knee was resisted by a soft object.

The roentgenograms were reviewed postoperatively in an attempt to see whether a submeniscal position could have been predicted. The only observation which may be of value was that the object was very near the level of the tibial plateau, and that foreign bodies in the posterior compartment, as ordinarily understood, would be expected on a level higher than the tibial plateau by about the thickness of the meniscus.

Platt has recommended what was attempted by the author, namely "compartmental" surgery of the knee. He states that "the joint cavity is divided into five distinct but intercommunicating compartments—three in front and two behind". These are the suprapatellar, the anterolateral, the anteromedial, the posterolateral, and the posteromedial. It would seem that these must now be increased to include the two anterior submeniscal and the two posterior submeniscal compartments. The various compartments of the knee joint

are formed by synovial reflections. Fullerton has made an excellent study of the surgical anatomy of the synovial membrane, and the submeniscal pockets are clearly outlined. Snell has filled the knee joint with a radiopaque material, and by roentgenogram has demonstrated these pockets bulging posterior and inferior to the menisci.

Much of the information on suppurative arthritis has come from war experience with compound wounds of the joint, in which foreign bodies were retained. Postoperative infection of this joint has been studied by Milch and Raisman, and their conclusion was that the incidence of infection varied directly with the complexity and the duration of the operation and with the size of the incision.

In this case, the operator was particularly vigilant not only of his own technique, but also of that of every member of the team. No break in technique came to his attention. Because of the curious submeniscal location of the foreign body, the operation was complex and long. However, neither the beach sand nor the sea shell was sterile when it was introduced into the knee. The patient had had a few febrile episodes of pain and swelling of the knee, which must be looked upon as transient and very mild attacks of suppurative arthritis. The temperature was already 103 degrees, within twenty-two hours of the closure of the skin, instead of after the usual three to five days, when infections from faulty technique are expected. Consequently, it seems more likely that the infection resulted from the removal of contaminated material from the joint with the breaking down of the protective wall of fibrous tissue.

The management of suppurative arthritis of the knee can be difficult. One is confused by the numerous methods in the literature, but all of them have three common features.

The first of these is evacuation of the pus, whether or not the joint is drained surgically. The greater number of surgeons favor drainage. On the other hand, some rely upon aspiration, either single or multiple, to evacuate the pus.

The second principle is an attempt to sterilize the contents of the joint, chemically, mechanically, or by chemotherapy. Chemical sterilization is illustrated by the use of iodoform gauze, flavine, mercuric chloride, ether and "bipp", peroxide and carbolic, phenol and camphor, or ether. In most of these methods, the mechanical effects of dilution and lavage cannot be excluded. Some surgeons have utilized irrigation with saline alone to bring about the desired result of sterilizing the joint fluid. Perhaps in the future such drugs as penicillin, as it was used in this case, will prove to be of the utmost value in cleansing joints.

The third principle in the management of suppurative arthritis, especially in the knee, is the question of motion or immobilization. It has been pointed out that absolute rest of the part is one of the best ways of combatting infection and of ensuring the later mobility of the joint[4,18]. However, some writers have felt that motion in the joint expresses the purulent material from the various pockets, and prevents formation of adhesions and muscle atrophy. The motion may be either active, assisted active, or passive in traction, as in the case reported here.

Tobin, Eggers, and Everidge have described apparatus not unlike that used in this case to give passive motion in traction. The advantages of this method are that the joint surfaces are distracted somewhat, and, therefore, do not become eroded; that the muscle spasm and pain are relieved by traction; that the motion of the joint empties the pockets of pus and prevents the formation of adhesions; and, lastly, that it can be carried out by the patient himself.

It would seem desirable, therefore, to treat suppurative arthritis of the knee by early surgical drainage, by thorough irrigation at operation, leaving the wounds open without drains, and by early passive motion in traction. When surgical drainage seems undesirable, daily irrigations through an aspirating needle plus the intracapsular administration of penicillin are at least feasible, and may in the future prove to be the best method.

NOTE: For critical readings of this report, acknowledgment is gratefully made to Dr. S. C. Harvey and Dr. M. S. Eveleth, Department of Surgery, Yale University School of Medicine.

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A SPLINT FOR THE CORRECTION OF EXTENSION CONTRACTURES OF THE METACARPOPHALANGEAL JOINTS

BY LIEUTENANT COLONEL I. WILLIAM NACHLAS
Medical Corps, Army of the United States

Extension contracture of the metacarpophalangeal joints is a common sequel to injuries of the hands and arms. It is usually the result of prolonged splinting by plaster casts, prepared splints, contracture of the skin and tendons, or disuse resulting from nerve and blood-vessel damage in the upper extremity. After the contracture has developed, attempts to move the joints produce pain, so that the patient tends to continue the splinting subconsciously. A vicious circle is thus begun. There is, of course, a similar deformity resulting from intrinsic damage to the joints, but this constitutes a separate problem.

The proximal finger joints in extension are particularly prone to fixation, with contracture of the capsules, the capsular ligaments, and the periarticular structures. Bunnell points out that infiltration of serofibrinous material between the various layers surrounding the articulations causes interference with the gliding of the tissues. Furthermore, the collateral ligaments are normally so attached to the bones that, although they are relaxed when the joint is extended, they become taut when the joints are flexed. If these ligaments become fibrosed or shortened, they act as checkreins to prevent flexion.

The inability to flex these joints constitutes a serious disability, because the hand cannot be closed. When there is an associated stiffening of the interphalangeal joints, the entire hand is "frozen" or "congealed". The use of the hand as a prehensile instrument is lost. There is also marked impairment in the holding qualities of the hand, when the proximal finger joints alone are maintained in fixed extension.

Because of the importance of restoring to the hand its grasping function, a number of procedures have been used to correct this deformity. Physical therapy has been resorted to, but has proved to be of only limited value when used by itself. Manipulation of the joints under an anaesthetic is said to cause a tearing of the periarticular tissues, with resulting protective reaction that frequently leads to further splinting and fibrosis. Because of this, manipulative surgery has been decried by many authorities. Occupational therapy, properly used, has been helpful, but the course of treatment is long, and its efficacy is dependent on the cooperation of the patient. Surgical intervention offers prompter correction, and has consisted chiefly of excision of the capsule on either side of the affected joint.

In the belief that continuous mild traction can restore the flexibility of the tissues fairly promptly with less damage to the joint structures, there has been developed a traction device in which tension is supplied by rubber bands. The problems of controlling the degree of tension, the direction of the pull, the ease of adjustment, and the comfort of the patient all presented themselves, and it has been possible to meet these requirements without making the splint too complicated in construction or too difficult to control. The splint consists of two basic parts,—first, a foundation splint which serves to keep the wrist in a cock-up position, to supply a fixed point for the attachment of the traction bands, and to afford a simple adjustment for the direction of the pull; and second, the traction unit which includes the elastic bands that supply tension.

The foundation consists of a cock-up splint of the type that was at one time used for immobilizing Colles's fractures. It is placed on the volar side of the forearm and palm, and strapped to the arm by a broad webbing. A longer, narrower strap fixes the palm part of this splint, so that it does not slip forward in the hand to interfere with flexion of the metacarpophalangeal joints. A U-shaped wire bar is held attached to the cock-up splint

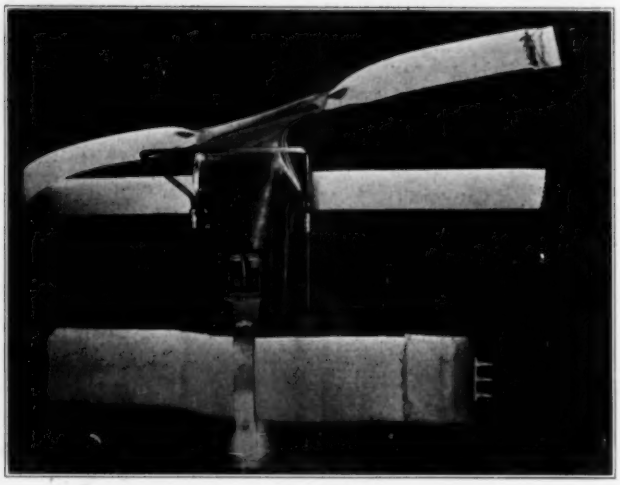

FIG. 1
Foundation splint with fixation straps.

by loops that permit the bar to be moved longitudinally. By regulating the position of this bar, one can control the direction of the traction. A buckle on the anterior surface of the splint supplies a point of fixation for the tension strap (Fig. 1).

The traction apparatus consists chiefly of a broad leather strap on the back of the hand, fixed at its proximal end by a webbing strap around the wrist (Fig. 2,*D*). At its terminal portion, this leather strap is cut longitudinally to digitate it. The end of each of these "digits" is sewn back on itself around a rubber band. The rubber bands for each of the "digits" are collected at their distal part, and held in a small wire catch that is sewed into a narrow leather strap which, in turn, is to fit into the buckle on the forearm. Specifications for the splint as it has been used in this hospital are as follows:—

SPECIFICATIONS OF SPLINT

Foundation Splint (Figs. 1, 2,*A*, 3,*A*, 3,*B*, and 3,*C*).

The material used is 18-gauge aluminum, three and one-half inches wide at the proximal portion, and three inches wide near the wrist. The forearm part is curved to fit the convexity of the volar surface of the forearm. At the wrist, the splint is bent up to hold the palm in the cock-up position. The distal end of the splint, which fits proximal to the metacarpal heads, is curved forward, so as to avoid cutting into the palm of the hand. On the concave side, there is glued a layer of light-weight sheepskin. In the palm of the hand, a metatarsal arch pad, three-eighths of an inch thick, is placed under the leather lining to permit maintenance of the transverse arch of the hand as recommended by Bunnell (*a* in Fig. 3,*B* and Fig. 3,*C*). On the convex surface, a monel-metal band is riveted longitudinally to serve as a strap retainer (*b*). The distal rivet also fixes a one-inch leather loop that holds a five-eighths-inch buckle (*c*). On the convex surface, near the long edges, there are riveted four monel-metal loops to grasp the sliding bar snugly without preventing its being pulled longitudinally (*d*). The sliding bar (*e*) is made of one-eighth-inch wire, and forms a U with the two arms of the U inserted through the monel loops. Near the wrist, the sliding bar is bent forward to form an angle of 120 degrees. Two webbing straps are used to fix the splint to the hand, the first (*D*) a two-inch webbing, twelve inches long, with a two-inch buckle to be slipped through the monel strap retainer (*b*), and to be buckled on the back of the forearm; the other (*E*) a one-inch webbing belt, twenty inches long, and with a one-inch buckle used to fix the distal end of the splint. If there is any tendency for the strap to slip off, two punch holes, one-quarter of an inch in diameter, may be made in it to fit over the corners at the end of the splint. The strap may be further secured by the sheepskin lining over it, as in Figure 1.

Traction Unit (Figs. 2,*D* and 3,*F*).

A piece of calfskin is cut to conform to the back of the hand and the proximal phalanges (*g*). The distal portion is cut longitudinally to permit four digitations, the ends of which are sewed back on themselves (*h*) around medium-heavy rubber bands (*k*). The

length of this leather should be such that, when it is fixed by a webbing strap and buckled (*f*) around the wrist, its digital ends (*h*) will reach just beyond the knuckles (first interphalangeal joints). The four rubber bands are then fastened by means of a wire rectangular loop (*m*), one and one-quarter by three-quarters of an inch, made of one-eighth-inch wire, to a leather strap (*n*), five-eighths of an inch wide and five inches long, with perforations at intervals of one-half of an inch for the buckle on the foundation splint. The thumb, because of its special mechanics, does not usually require traction.

APPLICATION OF THE SPLINT AND MODE OF ITS USE

The foundation cock-up splint is placed on the volar aspect of the arm and palm, with the terminal portion kept proximal to the crease in the hand (Figs. 4, 5-A, 5-B, 6-A, and 6-B). The broad webbing belt fixes the forearm part. The long narrow strapping is then applied in such a way that it will prevent the displacement of the brace distally. This is quite important. If the brace is pulled toward the fingers, it blocks flexion of the metacarpophalangeal joints. The strapping is stretched across the terminal portion of the brace, and then is looped around the back of the wrist in a figure-of-eight which crosses on the back of the hand. The buckle should be placed in such a position that it will not be under the leather piece of the traction unit (Figs. 5-A and 5-B). The traction unit is then applied in the following manner: The leather piece is placed on the dorsum of the hand, and fixed in position by means of a webbing around the wrist. The fingers are then passed through the rubber bands with the leather digitations reaching just distal to the proximal interphalangeal joints (Figs. 6-A and 6-B). The sliding bar is adjusted to a position which will permit the direction of the pull to be where desired. The

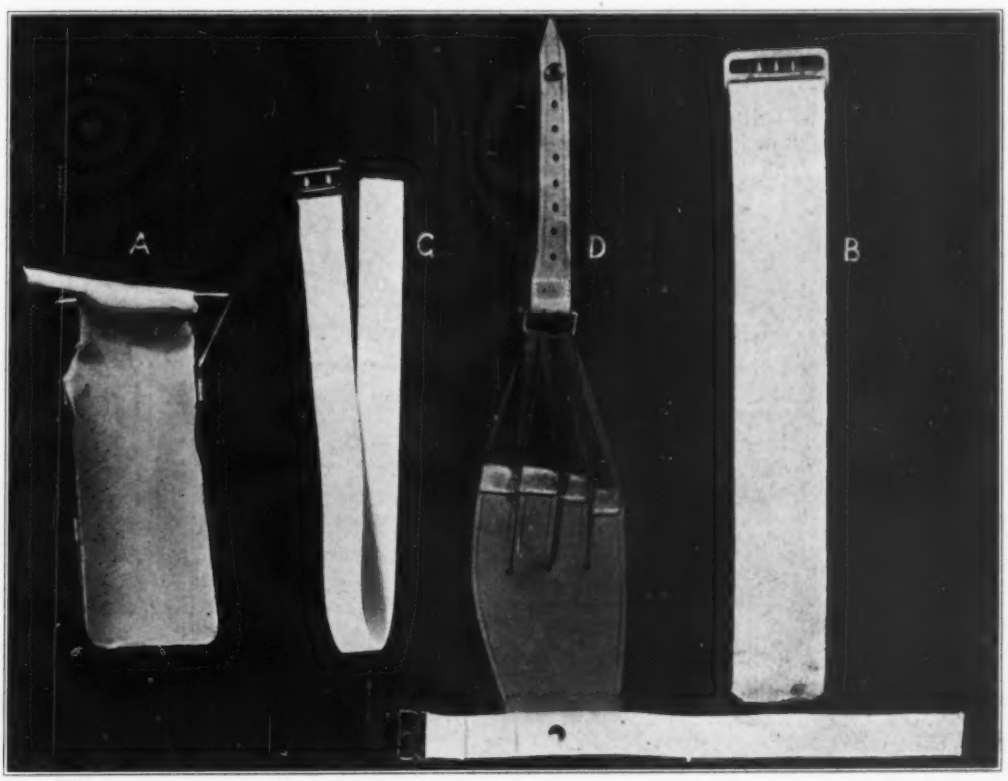

FIG. 2

Individual parts of the splint. *A:* Concave aspect of foundation splint. *B:* Forearm strap. *C:* Strap for fixation of palmar portion of splint. *D:* Traction unit.

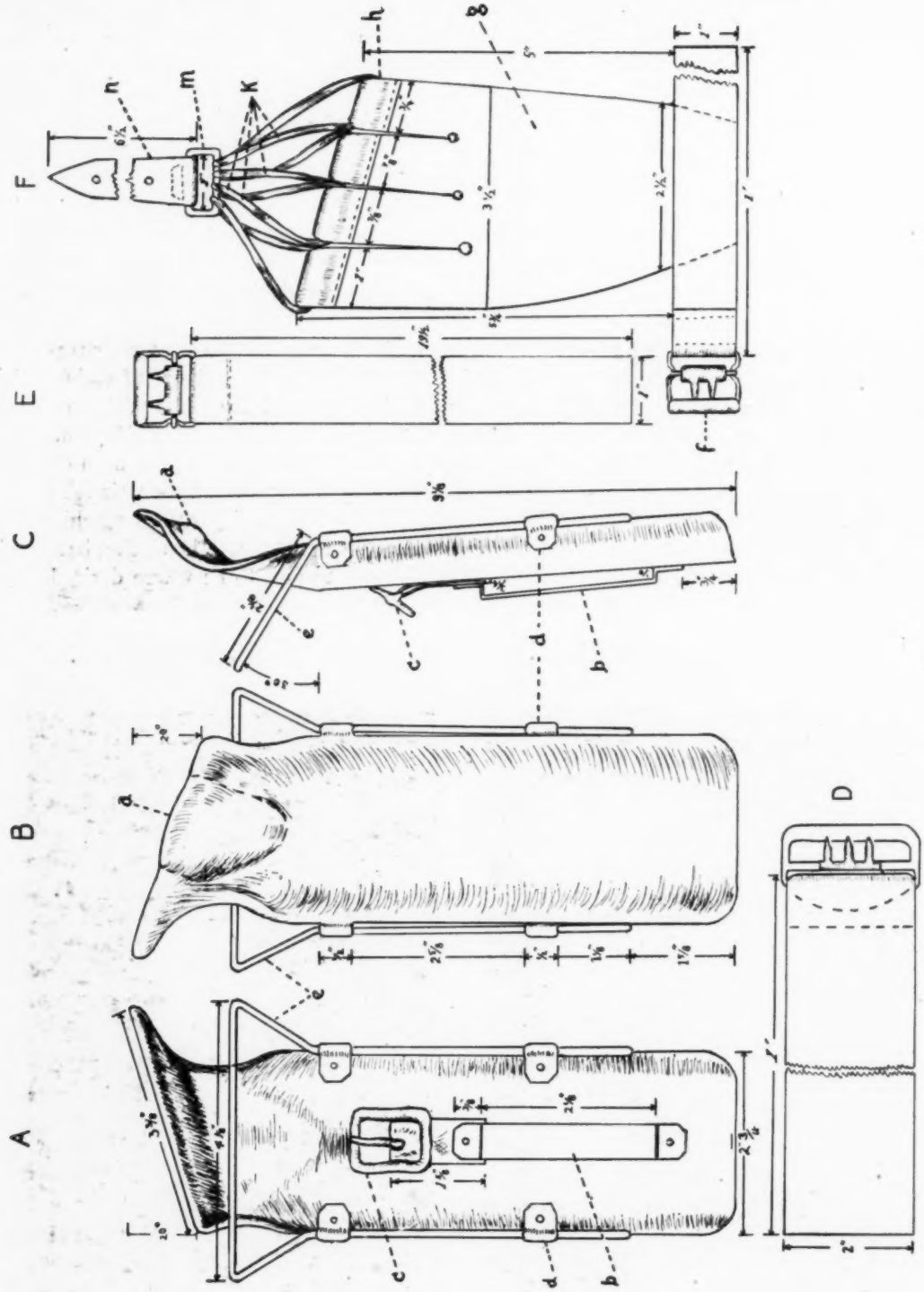

FIG. 3
Drawings of the component parts of the splint with measurements of a standard model.

strap on the other end of the rubber bands is then pulled over this bar, and is fixed to the buckle on the volar surface of the brace at the desired tension.

It is desirable that the brace be inspected daily so that the direction of the pull may be changed, and the amount of traction altered to meet the changing position of the fingers. It will be noted that the terminal parts of the fingers are given freedom of action, and the patient should be encouraged to use his fingers in full extension and flexion, when the brace is being worn. The use of these joints is of considerable value in restoring gliding function and necessary length to the tendons. It is desired that the splint be worn throughout the day, but it may be removed for short periods of time to permit the patient to wash his hands and to actively exercise his hand and fingers.

The splint is intended for the treatment of extension contractures of the metacarpophalangeal joints. When used for this purpose, it may be expected to help restore flexion in a relatively short period of time,—from several days to several weeks. After a fair arc

FIG. 4

Photograph of a hand with extension contractures of the metacarpophalangeal joints.

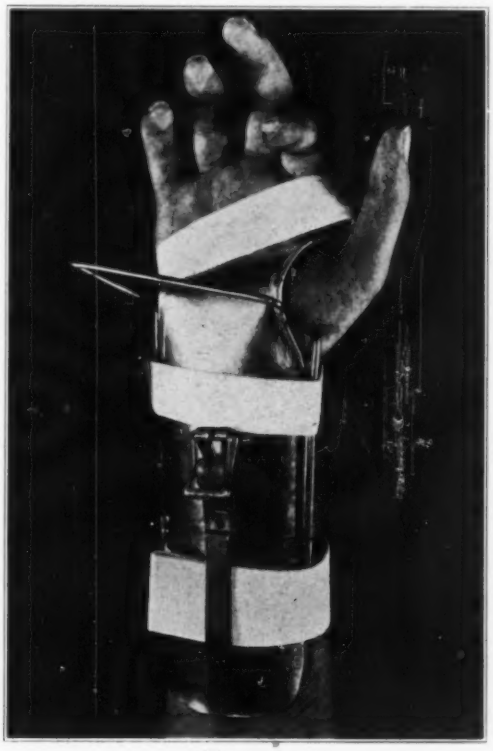

FIG. 5-A

FIG. 5-B

Photographs of a "frozen" hand wearing the foundation splint.

Drawings of the component parts of the splint with measurements of a standard model.

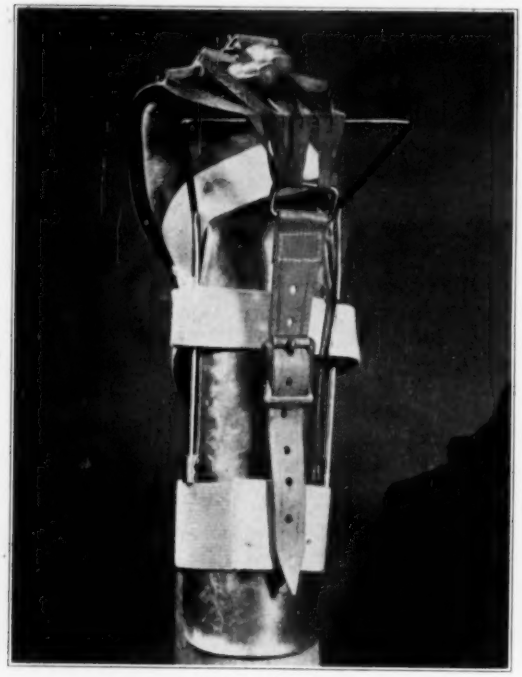

FIG. 6-A

FIG. 6-B

Splint assembled on hand. Volar and dorsal views.

of motion has been acquired (usually two-thirds of the normal range), it is desirable that for at least part of the day the splint be removed, so that occupational therapy may be used. In addition, physical therapy is usually helpful at this stage of the patient's progress.

The successful use of the splint in fifty consecutive cases warrants its recommendation for the specific purpose for which it has been designed.

CORRECTION OF POLIOMYELITIC DEFORMITIES WITH FROTHED LATEX PROSTHESES

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In the past two decades, spurred no doubt by the casualties of two wars, facial prostheses have come to have an established and recognized place in plastic surgery. As the public becomes accustomed to what is being done in the way of prostheses for the face, requests have come for restorations hitherto considered not only beyond the scope of plastic surgery, but also beyond the scope of prosthetics. One's first impulse is to tell such a patient that the restoration asked for is not being done. But the plastic surgeon who does prosthetic work must realize that his office or clinic is the court of last resort for such patients and, if he has no restoration to offer, the patient may become convinced that his case is hopeless. We are besieged by requests not only to restore missing parts of the face, but also to restore the breasts, the hand, the buttocks, the penis, and the calf of the leg.

Small prostheses for the face can be made of solid rubber or hollow rubber, molded by relatively simple techniques. Prostheses for the breast, the buttocks, and the calf of the leg, if made by the same technique, would be heavy, bulky, unwieldy, and relatively non-resilient. They should be light enough in weight so that a relatively small amount of adhesive will keep them in place, or so that no adhesive at all is necessary. They should also, unlike facial prostheses, have the rebound elasticity characteristic of the organ which they replace. For instance, when the artificial ear is bent forward and released, it should spring back into place immediately, as does an ordinary ear. Likewise, the artificial calf of the leg when pressed with the finger, should rebound at the rate normal for calf tissues.

In this paper is presented the technique of making a prosthesis which restores the contour of the lower limb, correcting the deformity caused by atrophy of the limb. The deformity is usually caused by poliomyelitis, and is the result of atrophy of the muscles themselves. Other defects, such as shortening of the limb, may be present in the affected extremity. These are corrected by operation to eliminate the limp, before the patient presents himself for a prosthesis. Atrophy of the foot is generally untreated, except for stuffing the normal size shoe with cotton or orthopaedic pads to make the inside of the shoe small enough to fit the foot. Even after the gait is normal, the slender "broomstick" appearance of the affected limb attracts unfavorable attention. It is to correct the thinness of the limb that such a patient desires a prosthesis.

The technique is as follows: The limbs are coated lightly with petrolatum jelly (the hair need not be shaved off). A two-piece negative impression is made in soft plaster-of-Paris (Fig. 2), a mold being made of both the affected limb and the normal limb. The negative impressions are removed, then are reassembled, plugged at one end, and filled with alpha gypsum (Fig. 4). The negative portions are then removed and discarded. The patient is placed upright with his shoes on and the malleoli are identified by suitable marks upon the positive cast. The positive casts of both the deformed limb and the normal limb are mounted vertically on a small plaster pedestal, so that the malleoli of the normal and of the deformed limbs are at the same distance from the work table (Fig. 5). The positive plaster cast of the normal limb is used as a model for the reconstruction of its mate. This eliminates numerous visits by the patient to pose for the sculpture of the prosthesis. With the normal cast as a model, sculptors' clay is applied over the cast of the deformed limb and is molded to the shape required, in bold sweeping contours to match the normal limb. This is checked with a caliper, so that the diameters at all levels of the two casts are almost

equal. The sculpture is so performed that the restored limb is made a little larger in all diameters to allow for the very slight shrinkage of the prosthesis during vulcanization. Once the sculpture has been completed, the clay is smoothed down with wet cotton wipes, and is permitted to dry smooth. It is then painted with a fine varnish. The varnish is applied so that, when the flask is made later, the plaster adjacent to the sculpture will not dry at a faster or slower rate than the other plaster in the mixture. Evenness of crystallization tends to make for a stronger cast.

The ensemble (Fig. 6), consisting of the model of the deformed limb bearing its sculptured and varnished restoration, is now a core around which is built a two-piece mold. This is done by imbedding the ensemble longitudinally halfway into a fresh mixture of alpha gypsum plaster, contained in a long cardboard box. After this has hardened, a petrolatum, a soap solution, or a commercial separating compound is applied to the surface of the plaster still exposed, and the remainder of the cast is made by pouring another batch of alpha gypsum mixture over the ensemble, as illustrated (Fig. 7). This is permitted to dry for several days, since it is necessary to permit the entire cast to dry evenly and thoroughly in exact position for at least several days in order to prevent warping.

When thoroughly dried, the cast is carefully pried open. The model of the deformed leg is removed, and the clay is washed out thoroughly. The three portions of the cast may then be dried and reassembled (Fig. 8). If some of the shellac, varnish, or lacquer remains clinging to the inside of the plaster mold, it may be removed by rubbing with acetone, ether, or alcohol. This gives the inside of the plaster mold the same porosity throughout. The reassembled mold now consists of two halves of a rather thick hard plaster shell, bearing longitudinally between them a core which is a replica of the *deformed* limb.

Unlike the casting procedures for the smaller facial prostheses, it is not necessary to construct a flue or pouring channel for prostheses of the limb. The prosthesis is made of frothed rubber; if it is to be made of commercially frothed or sponged rubber, it is necessary to reproduce the entire cast in aluminum. This may be done in an aluminum foundry; however, this procedure is time-consuming, tedious, and expensive. We now use a rubber compound which, unlike commercially frothed or sponged rubber, does not require vulcanization under extreme heat and pressure. Therefore, the prosthesis may be processed in the original hard plaster cast. The dry mold

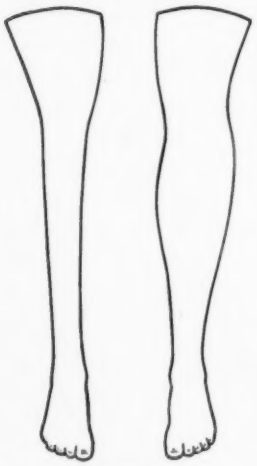

FIG. 1
Comparison between lower limbs with and without poliomyelitic deformity.

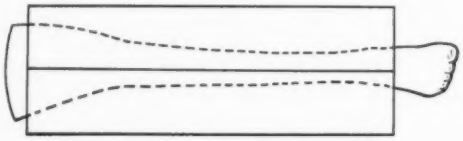

FIG. 2
Two-piece negative mold.

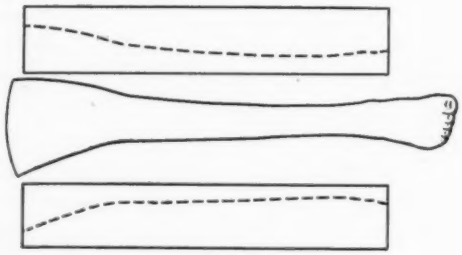

FIG. 3
Two-piece negative impression disassembled.

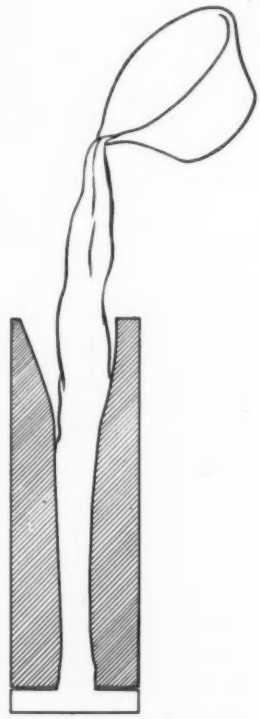

FIG. 4
The bottom is blocked, and the negative impression is filled with hard plaster-of-Paris.

is laid open preparatory for casting. The materials which are used for making frothed latex prostheses are generally bought in the form of a latex compound or a latex compounding dispersion. However, for those who intend to make prostheses, a typical formula for a frothing stock follows:

	Parts by volume
Rubber (as latex, 60 per cent. solids)	100
Sulphur	2
Zinc oxide	2
Zinc mercapto benzothiazole	1
Zinc diethyldithio carbamate	1
Potassium oleate	2
Sodium fluosilicate	1

All of the above ingredients must be dispersed or dissolved in water, so as to be compatible with the latex. There are many other accelerators and soaps, known to the rubber industry, which could be substituted for those shown above, depending upon the properties of the latex and upon processing conditions. However, the compound made up as described requires the minimum of laboratory equipment and offers fewer disappointments.

As we use the compound now, the potassium oleate or soap, the zinc compounds, and the sodium fluosilicate are kept in separate containers. They are combined only

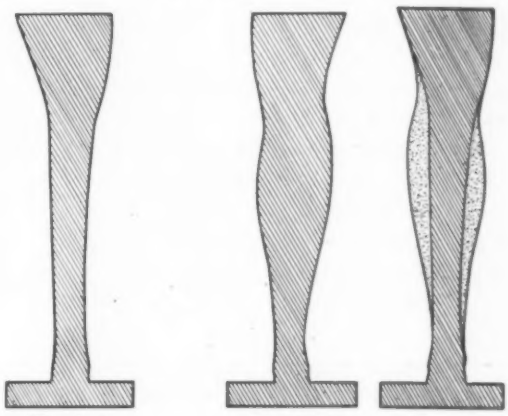

Fig. 5-A Fig. 5-B Fig. 6

Fig. 5-A and Fig. 5-B: The negative casts are discarded, and the positive cast of the deformed limb (Fig. 5-A) is mounted on its plaster base.

Fig. 6: The mirror image of the normal limb is sculptured in clay upon the model of the deformed limb. This is varnished.

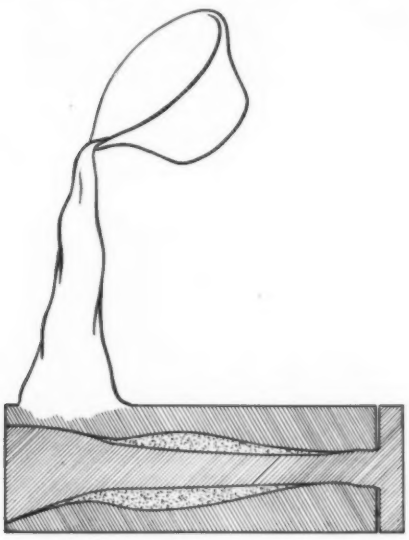

Fig. 7

The model of the deformed limb, sculptured up to normal dimensions, is invested in a two-piece alpha gypsum mold.

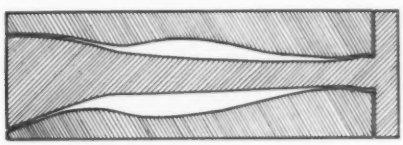

Fig. 8

The clay has been washed out. The mold, reassembled, now consists of two external dies and a core.

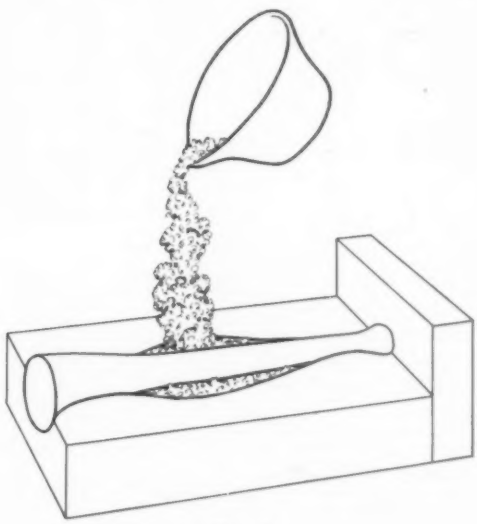

Fig. 9

The two halves of the mold are filled with frothed latex compound, the core is replaced, and the mold is assembled. It is now ready for vulcanization.

when the frothing process is ready to be begun and when the mold is ready to be cast. Others of the ingredients may also be held out of the compound, so as to prevent premature vulcanization. The rubber compound, one-fifth of the volume necessary to fill the mold, is placed in an electric beating machine or rapid mixer, and the compound for frothing (potassium oleate) is added. As the beating continues, suitable colors are added to the agitated mixture. The following colors, each in a 3 per cent. ammoniated solution (since they disperse

FIG. 10
Typical poliomyelitic deformity. Note asymmetry.

FIG. 11
Showing the latex prosthesis.

FIG. 12
Prosthesis being slipped on like a stocking.

FIG. 13
Prosthesis in place. Note the symmetry of the limbs.

better, when ammoniated), are used, generally one or two drops of red and brown for each ounce of rubber:

DC Red No. 7,
Sudan orange, RRA,
Amido naphthol brown,
Fast scarlet, BA.

Beating the mixture for five or ten minutes is usually sufficient to froth it until its volume is increased about five or six times. When this has been accomplished, the zinc compounds are included, and the mixing is continued for another one or two minutes to disperse the zinc. The sodium fluosilicate is added, and the beating continues for another minute to disperse it well. The frothed mixture, which is extremely light and airy, is then immediately poured into the mold with the core assembled (Fig. 9), and enough excess mixture is added so that, when the entire mold has been assembled, the excess of the frothed rubber will extrude from the mold. The assembled parts containing the rubber are permitted to stand undisturbed for a few hours and are then wired firmly together with stove wire or baling wire. The vulcanization is accomplished by immersing the cast in boiling water for approximately an hour and a half. (If an autoclave is available, the ensemble will be cured after approximately fifteen minutes in steam at 250 degrees Fahrenheit, at fifteen pounds gauge pressure. Vulcanization is possible in an oven, too, but the time will be longer because of poor heat transfer.) Next the cast is cooled, either in the air or under running water. The parts are disassembled, but the prosthesis remains encircled about its core. The rubber part is now rinsed well under tepid running water, the excess water is squeezed out by manual pressure, and the prosthesis is permitted to dry from one to two days at room temperature to finish the curing process. The rubber prosthesis is then removed from its core (it may be washed and dried), the flashing is cut away, and the marks of the cast edges are removed with fine manicure scissors or obliterated by gentle application of a small revolving dental granite stone. There is generally enough shrinkage so that, when the prosthesis is put on like a stocking, it remains firmly in position.

This type of prosthesis is extremely light in weight and is very comfortable to wear, possessing as it does a rebound elasticity, unlike that of prostheses for the face. Pressed or indented with the thumb or fingers, the surface rebounds in almost exactly the same way as does skin. When stockings are worn, the deformed limb cannot be detected by casual inspection.

The colors used for these prostheses are different from those employed in other prostheses. Since this air-frothed rubber is heat-vulcanized, the coloring materials must be not only alkali-fast, and sun-fast, but also heat-resistant.

One has only to see the gratitude shown by patients who are given prostheses of this type to restore deformities of the lower limb to realize that such prostheses have a real place in the field of plastic surgical prosthetics.

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A MODIFICATION OF THE DENIS BROWNE SPLINT

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AND
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The correction of congenital talipes equinovarus is admittedly a problem. The use of the Denis Browne splint has been the simplest solution in most cases. No matter what method or combination of methods is used to obtain a corrected position, however, the process of correction is only partially complete, for there still remains the problem of maintaining the feet in the desired position of overcorrection for a considerable period, often years.

FIG. 1
Details of splint attached to shoes.

The writers wish to describe their modification of the Denis Browne splint, the use of which has several advantages, both to the patient and to his attendants. It consists of a transverse steel rod about five-eighths of an inch (1.6 centimeters) in diameter, and is a length suitable for the size of the patient. To each end of this rod is welded a clamping mechanism which grips the soles of the shoes in the manner illustrated, much like roller or ice skates. In addition, posterior T straps are incorporated into the sole clamps. These straps are laced around the patient's ankles with regular shoe laces. In many cases these T straps may not be necessary, but they tend to prevent recurrence of equinus deformity.

This splint has the following advantages:

1. It can be applied to shoes so that the corrective effect the patient receives from his shoes during periods of weight-bearing is continued by the splint during non-weight-bearing periods.

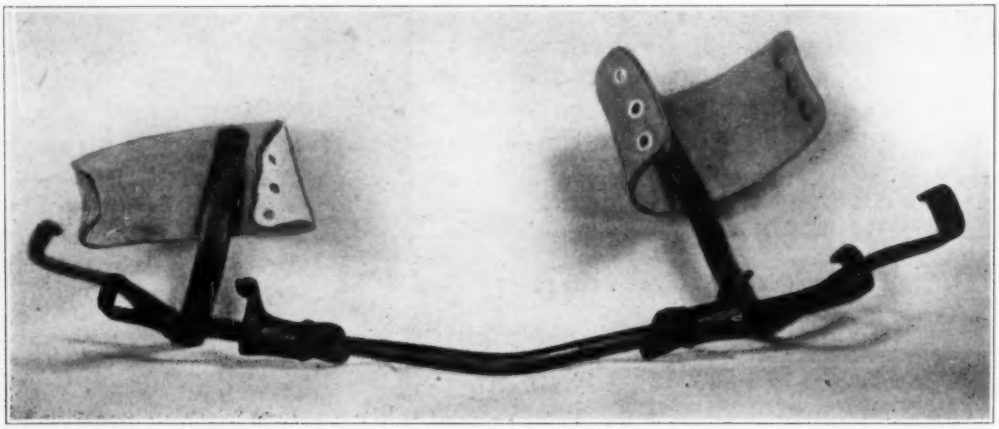

FIG. 2
The splint unclamped from shoes.

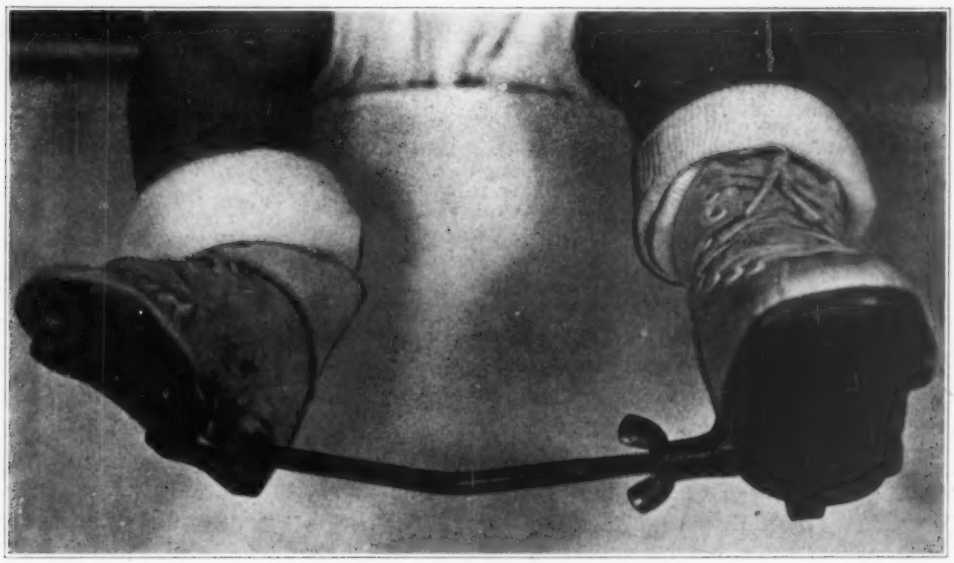

FIG. 3
A patient with the shoes and splint applied.

2. There are no projections on the under surface of the splint, so that the patient can stand up in his crib without puncturing or ripping his bed clothing.

3. Only one pair of shoes is required at a time: an important economic feature, since the shoes can be used for ordinary walking or standing when detached from the splint.

4. The splint is easily made, and can be applied and removed in only a few seconds, so that its use does not involve any great trouble to the patient's parents or attendants.

The usual way in which the writers employ their modification of the Denis Browne splint is to use it continuously with the patient's shoes reversed, until the infant begins to stand and walk. Then the shoes are worn on the correct feet, and a lift is incorporated into the lateral sides of the heels and soles of the shoes so that, when the patient is bearing weight, his ankles are thrown into slight valgus position. Then, during morning and afternoon naps as well as at night, the splint is applied and continues the corrective effect.

A THIRD ROUTINE X-RAY EXPOSURE OF THE ANKLE JOINT

BY R. S. SIMON, M.D., JERUSALEM, PALESTINE

It has long been the practice to take the anteroposterior and lateral views in roentgenograms of the ankle. These projections may not always show clearly all bone lesions in the fibula. To obtain an oblique view of the lower part of the fibula, a special exposure is necessary. In Figures 1-A and 1-B the lateral malleolus is on the side of the film; the heel is raised four centimeters, and the picture is made, with the central ray directed from behind at an angle of 30 degrees.

This oblique projection shows fractures of the fibula (Fig. 2-C) which might not be clearly visible in the usual lateral view, because the shadow of the fibula is obscured by the shadow of the tibia. While the technique described is not original, its routine use would ensure more accurate diagnoses.

FIG. 1-A

Position of foot for x-ray, with door-stop under os calcis.

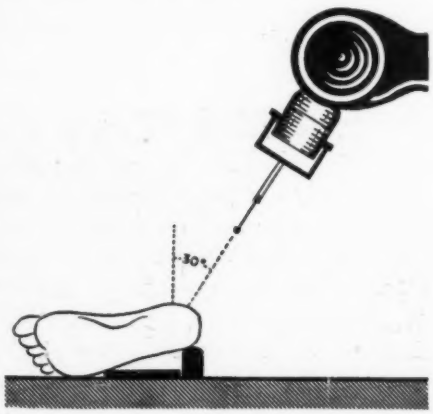

FIG. 1-B

Position of third routine exposure.

FIG. 2-A

Three exposures of ankle joint.

FIG. 2-B

The special exposure (Fig. 2-C) shows the real extent of fracture.

FIG. 2-C

AN EASY AND ECONOMICAL METHOD OF MAKING REMOVABLE CASTS

BY M. LAURENS ROWE, M.D., CINCINNATI, OHIO

From the Orthopaedic Department of the College of Medicine of the University of Cincinnati, and the Orthopaedic Service of the Cincinnati General Hospital

Rigid splints and supports of various types, which can easily be removed, are frequently desirable in the management of orthopaedic problems. Bivalved plaster casts can be used for intermittent immobilization of the extremities, but they often pinch and bind or slip out of position, and they are inadequate for neck or trunk splinting in the ambulatory patient.

A method, used by the staff of the 297th General Hospital for the application of lumbar body jackets, which involves the incorporation of strips of used x-ray film into ordinary plaster casts, has proved to be economical and efficient.[1] This simple technique of making circular plaster casts for the body has been applied to casts for the neck or the extremities, at the Cincinnati General Hospital, and these have been found to be sufficiently flexible to permit removal and reapplication without cracking.

The cast is applied snugly over stockinette without sheet wadding, and is carefully

FIG. 1

Cervical spine collar opened from behind, to demonstrate circumferential flexibility.

FIG. 2

Lumbar body jacket opened to illustrate flexibility.

molded over bony prominences. Strips of used x-ray film are laid between the layers of plaster in a generally circumferential direction at varying angles to give roughly uniform distribution throughout the cast. Strips, two inches wide and twelve inches long, are most convenient for the larger body casts, and strips, six inches by one inch, are used in the cervical spine collars and in casts for the extremities. In the usual lumbar body jacket, for instance, five to seven rolls of six-inch plaster and twelve to fourteen strips of x-ray film are used, making a cast about a quarter of an inch thick. Comparable amounts of plaster and x-ray film are employed in the other casts.

A narrow strip of felt is placed under the stockinette along the line on which the cast is to be cut for removal. After the plaster has set, the cast and stockinette are cut along the felt strip and are removed by spreading. The cast is then bound back into its original shape with gauze bandage to prevent warping, and is dried for twenty-four hours. The cut edges are taped, and the cast is fitted with straps and buckles. The completed cast is

[1] A Removable Plaster of Paris Back Support. (News and Comment.) Bull. U. S. Army Med. Dept., LXXIX, 11, 1944.

rigid in its long axis, but sufficiently flexible in a circumferential plane to permit easy removal and reapplication without cracking the plaster.

It is felt that this type of cast embodies all the advantages of the celluloid jacket and offers, in addition, simplicity of application and extreme economy. It may often be used in place of formal braces and appliances where, for one reason or another, these are unobtainable.

A SIMPLE GUIDE PIN FOR THE INSERTION OF DEVICES OF INTERNAL FIXATION INTO THE FEMORAL NECK

BY M. LAURENS ROWE, M.D., CINCINNATI, OHIO

From the Orthopaedic Department of the College of Medicine of the University of Cincinnati, and the Orthopaedic Service of the Cincinnati General Hospital

To determine the proper length and angle of insertion of the nail or other fixation device used in fractures of the neck of the femur, a simple modification of the Steinmann pin, as shown in Figure 1, may be employed. Beginning at the pointed end of an ordinary Steinmann pin, slots have been filed at half-inch intervals for a distance of five inches. Each slot extends halfway through the thickness of the pin, so that a clear roentgenographic image may be obtained. At a distance of five inches from the point is a one-inch oblique offset, the angle formed between the offset and the long axis of the pin being 125 degrees, an approximation of the normal angle between the femoral neck and shaft.

The fact that the offset makes an angle of 125 degrees with the long axis of the pin is a helpful check feature since, when properly inserted, the offset lies parallel to the shaft of the femur. The slots indicate the correct length of the fixation device to be employed.

The pin is inserted through a drill hole in the cortex, and the angle of the femoral neck is determined by gentle palpation of the medullary cavity, after the method of Watson-Jones.

The marker pin may be inserted at the base of the greater trochanter, and the nail or other fixation device is then driven parallel to and just below it in optimal position. Or the nail may be driven into place in actual contact with the guide pin, superiorly or inferiorly, anteriorly or posteriorly, according to the indications of the check roentgenograms.

Turning the offset away from the side on which the nail is to be inserted provides

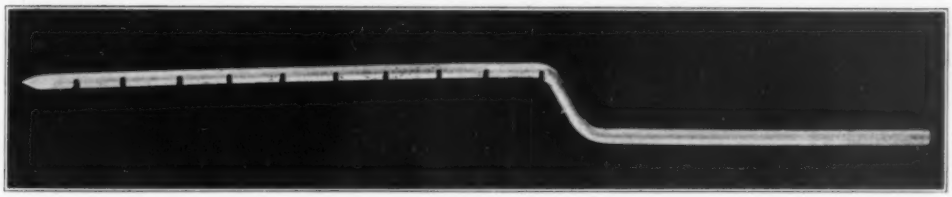

FIG. 1
Photograph of the guide pin.

FIG. 2
The guide pin has been inserted relatively high in the femoral neck. A Smith-Petersen nail has been introduced below and parallel to the guide pin in optimal position, and has been driven partially into place. The offset is turned away from the nail to provide adequate space for the nail and its driver.

ample space for the driver and, since the measured slots are on the same side of the pin as the offset, affords a smooth surface of pin along which the nail may be driven.

After the nail, blade, or other fixation device has been driven, the marker pin is easily withdrawn with a hand chuck, and final impaction may be carried out and check roentgenograms taken.

The pin combines the advantages of an adequate direction finder, an accurate internal measuring instrument, and a direct and solid guide for the driving of most devices of internal fixation, designed to be inserted into the femoral neck.

W. A. COCHRANE, F.R.C.S. EDIN.
1893–1944

William Alexander Cochrane died at the age of fifty-one in Edinburgh, on November 30, 1944. He is survived by his wife, and a young son and a daughter.

A native of Edinburgh, he received his education at Daniel Stewart's College and at Edinburgh University where he received the degrees of Bachelor of Medicine and Bachelor of Surgery in 1915. Thereafter, as a battalion medical officer, he saw service in France and Flanders, where he was wounded. The wound, a compound fracture of the leg, required active treatment for nearly two years, and this circumstance was largely responsible for turning his thoughts toward orthopaedic surgery. During the latter part of his treatment he was in Bangour Hospital, a temporary military hospital located near his native city, and here later he acted as house surgeon. The Orthopaedic Staff of the Hospital consisted of British and American surgeons, under the immediate direction of Sir Harold Stiles and the more distant control of Sir Robert Jones in his capacity of Inspector of Military Orthopaedics. His association with these two great leaders made an indelible impression upon Cochrane, and from that time he determined to devote his life to the study, the practice, and the furtherance of orthopaedic surgery in Scotland.

After a period of study at Continental clinics, he went to the United States of America, where he acted as a temporary assistant in orthopaedic surgery at the Massachusetts General Hospital in Boston. Cochrane used to refer to Boston as his second spiritual home, and certainly he owed an immeasurable debt to the inspiring teaching of Dr. Joel E. Goldthwait and Dr. Robert B. Osgood, especially in the sphere of medical orthopaedics.

He returned to Scotland in 1921, and took the Fellowship of the Royal College of Surgeons of Edinburgh. At the Royal Infirmary he acted first as Clinical Tutor in the Clinic of Professor Sir Harold Stiles, and later as Assistant Surgeon in the Clinic of Professor Sir David P. D. Wilkie. While his primary interests remained in orthopaedic surgery, during the tenure of these offices, he had an excellent opportunity of obtaining a wide experience in general surgery, which he always maintained was an essential part of the training of an orthopaedic surgeon.

Later he became Associate Assistant Surgeon in Orthopaedics at the Royal Infirmary, and Lecturer on that subject in Edinburgh University. The Edinburgh Orthopaedic Clinic and the Edinburgh Foot Clinic owed much to his service and practical help. In 1934 he played a very active part in the founding of the Princess Margaret Rose Hospital for Crippled Children, of which he was the Surgeon-in-Charge. This Hospital was the first Orthopaedic Hospital built in Scotland. Its extension was curtailed by the outbreak of hostilities, but, by that time, Cochrane had the satisfaction of seeing the Hospital well established, with a network of major and minor clinics covering the southeastern region of Scotland. During the War, Cochrane acted as surgeon to the Emergency Medical Service, and was a Consultant Orthopaedist to the southeast area of the Scottish Command.

In addition to his hospital appointments, Cochrane acted on many committees, and his advice was frequently sought and willingly given on all matters relating to cripples. He was a member of the committee responsible for the Delevingne "Interdepartmental Report on the Rehabilitation of Persons Injured by Accidents"; a member of the National Advisory Council for Scotland on Physical Training and Recreation; a member of the Council of the British Orthopaedic Association and of the Scottish Orthopaedic Council. For twelve years he was Assistant Honorary Secretary to the Edinburgh Branch of the British Medical Association, and, at the Annual Meeting of the Association in Winnipeg in 1930, acted as vice-president of the Section of Orthopaedics. He was the author of a textbook on "Orthopaedic Surgery" in 1926; and, jointly with Philip D. Wilson, of "Fractures and Dislocations" in 1925. His contributions to the literature on a wide variety of subjects were distinguished by their clarity, simplicity, and authority.

Big, breezy, and downright, Cochrane had many interests outside his profession. A scratch golfer, he was well known and popular on the golf courses of Edinburgh and East Lothian. His enthusiasm for the game and his skill did not diminish with the years. His tall, striding figure and jovial laugh will be missed at the Association golf meetings.

Cochrane was outstanding in the broad view he took of his specialty. He deprecated the tendency of regarding the orthopaedist principally as an operating surgeon. He was enthusiastic in his advocacy of medical orthopaedics, and, as an exponent of sound body mechanics, he maintained that the orthopaedist's field included the supervision of general physical education from infancy. One of his frequent remarks was that one could not derive full satisfaction from any reconstructive operation, however successful, unless one could be sure that every opportunity had been first provided for the patient to avoid the operation by adequate primary treatment. To his mind the ultimate aim of the orthopaedist was preventive medicine.

A pioneer in the Scottish orthopaedic field, Cochrane's loss will be widely felt, especially in these days of change in medical politics and services; but by his skill, ready sympathy, enthusiasm, single-mindedness, and hard work he has done much to advance his specialty, and has built a foundation on which much that he worked for will surely rise.

SAMUEL CLIFTON BALDWIN
1855–1944

Dr. Samuel Clifton Baldwin, of Salt Lake City, died on October 19, 1944, at the age of eighty-nine. One of the pioneers of orthopaedic surgery in the Far West, he was the first to specialize in orthopaedic surgery in Utah, and one of the best loved physicians in his State.

At the age of sixteen, upon the death of his father, Dr. Baldwin was faced with the problem of supporting his family. Although he was forced to leave school for a time, by dint of hard work and sacrifice, he entered the Louisville Medical College in his home State of Kentucky in 1881. He was graduated in 1884, and after ten years of practice, he went to Salt Lake City.

His work throughout the State was of a highly constructive nature. For many years he was Chief of the Primary Children's Hospital in Salt Lake City. He held membership in the Salt Lake County and Utah State Medical Societies. He was active on the staffs of the Dr. W. H. Groves Latter-Day Saints Hospital, Holy Cross Hospital, and the Salt Lake County General Hospital. Recently he received the honorary degree of Doctor of Science from the University of Utah, of whose Board of Regents he was a member, in honor of his work as a physician in Utah.

In 1903, Dr. Baldwin became a member of The American Orthopaedic Association, and he held memberships as well in The American Academy of Orthopaedic Surgeons and the American Medical Association. During World War I, he served as Lieutenant Colonel in the Army orthopaedic department, and although he sought active service in 1942, he was barred because of his age.

Dr. Baldwin is survived by a son, Albert B. Baldwin, and a sister, Mrs. Lillie B. Reynolds of Louisville.

CARL THORBURN HARRIS
1891–1945

Carl Thorburn Harris, one of the leading orthopaedic surgeons and teachers in central New York, died at his home in Honeoye Falls on April 17, 1945.

Born in Rochester, Dr. Harris received the Bachelor of Science degree from the University of Rochester in 1912, and then went on to the Harvard Medical School, where he was graduated with the degree of Doctor of Medicine in 1916. After a two-year period as surgical intern at the Boston City Hospital, he served overseas with Base Hospital Number 7, as an orthopaedic surgeon. He was a First Lieutenant in the Medical Corps.

At the close of the War, Dr. Harris returned to his native city, and became a teaching fellow in surgical pathology at his alma mater. He later was an Instructor, Assistant Professor, and Professor of Orthopaedic Surgery at the University of Rochester School of Medicine. He was active in medical circles in Rochester, serving as Chief of the Orthopaedic Service, Genesee Hospital; Consultant in Orthopaedic Surgery, Iola Sanatorium and Monroe County Hospital; and Attending Orthopaedic Surgeon, Highland Hospital. He was an Associate Visiting Surgeon at the Rochester General Hospital.

Dr. Harris was a Diplomate of The American Board of Orthopaedic Surgery, and a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the American Medical Association.

Current Literature

ESSENTIALS OF BODY MECHANICS IN HEALTH AND DISEASE. Joel E. Goldthwait, M.D., F.A.C.S., LL.D.; Lloyd T. Brown, M.D., F.A.C.S.; Loring T. Swaim, M.D.; John G. Kuhns, M.D., F.A.C.S. With a Chapter on the Heart and Circulation as Related to Body Mechanics by William J. Kerr, M.D., F.A.C.P. Ed. 4. Philadelphia, J. B. Lippincott Company, 1945. $5.00.

The appearance of a new edition of Body Mechanics is particularly timely, in view of the present concern with physical fitness. This is the standard book on a basic subject of significance to all branches of medicine. The new edition was prepared in order to make the subject clearer, and to present it more concisely. Body mechanics plays an important rôle in the prevention and cure of a great variety of diseases and disorders. It also is important in the palliation of the diseases of older persons. For this reason a chapter on geriatrics has been added.

The relation between form and function ought not, at this late date, to require either demonstration or defense. But it is unfortunately apparent that, in its application to hygiene and to the care of the sick. this principle does not receive its appropriate share of clinical attention. It is to be hoped that the appearance of this new edition will serve to promote a greater realization of the importance of body mechanics, and a wider application of the principles so forcibly presented.

In furtherance of the development of the young, in the maintenance of health in the adult, and in the prevention and palliation of the degenerative diseases of the elderly, body mechanics assumes vast proportions.

Because of these considerations, it is desirable that this well written and clearly illustrated book should reach a wide circle of students of all ages. Internists will find particularly revealing the sections dealing with the sympathetic nervous system, the circulatory system, and the joints. The relation between posture and physiological disturbances is clearly shown and the appropriate postural treatment is concisely outlined.

DOCTORS AT WAR. Edited by Morris Fishbein, M.D. New York, E. P. Dutton & Company, Inc., 1945. $5.00.

In "Doctors at War", there have been collected the medical accomplishments of Service doctors on every far-flung battle front. The sixteen foremost authorities responsible for the organization of our Wartime Medicine have written their own exciting accounts of what each branch of the Service has accomplished. In General Hawley's account, we learn how doctors in the European Theatre of Operations prepared for D-Day. Admiral McIntire writes of the duties of the Navy medical personnel, while at sea and under action.

Sharing the responsibility in a less exciting but nonetheless invaluable way, have been the doctors on the home front. Their services to the civilian in his home, and to the laborer in the factory, are given well-deserved praise. There are also interesting accounts of the medical side of Selective Service, preventive medicine as carried out by the Army, the United States Public Health Service, the Veterans Administration, and the Red Cross.

One of the paradoxes of war is that out of all the suffering, bloodshed, and death come medical discoveries which do much to advance the future welfare of mankind. During World War I, influenza was almost as deadly an enemy as enemy gunfire. Since then our doctors have isolated the responsible virus, and the disease is kept under control by drugs and vaccines. At present in the Army, the Bureau of Preventive Medicine includes some of the greatest experts in medicine, and they are dealing with respiratory diseases, air-borne infections, epidemics of all kinds, virus diseases, and tropical diseases. With war as the impetus, the medical knowledge and experience gained by our doctors has been tremendous. The records of lives of wounded men saved in the Army, Navy, and Marine Corps in World War II, as compared to World War I, is a hopeful indication of what medical and scientific progress can achieve in the peace which will follow.

MORRIS' HUMAN ANATOMY. A COMPLETE SYSTEMATIC TREATISE. Edited by J. Parsons Schaeffer, A.M., M.D., Ph.D., Sc.D. Ed. 10. Philadelphia, The Blakiston Company, 1943. $12.00.

There have been some changes in the list of contributors to the tenth edition of Morris' Human Anatomy. Some of the new contributors are: J. C. B. Grant, who has written the section on The Musculature; Bradley M. Patten, whose section covers The Cardiovascular System; Harold Cummins, writing on The Skin and Mammary Glands; and Olof Larsell, and C. M. Jackson, editor of former editions of this book, describing The Digestive System. Other sections include Developmental Anatomy, by

Richard E. Scammon; Osteology, and The Articulations, by Robert J. Terry; The Lymphatic System, by Eliot R. Clark; Special Sense-Organs, by Leslie Brainerd Arey; The Respiratory System, by J. Parsons Schaeffer, editor of this volume; Urogenital System, by Franklin P. Johnson; and The Glands of Internal Secretion, by J. F. Gudernatsch.

Each of the several sections has been revised and brought into line with accepted thought, and some have been extensively rewritten. There is an orderly presentation of each subject, and throughout reference is made in convenient places to the clinical aspects and relations of the systems being discussed. Many new illustrations have been added. The section on Developmental Anatomy appears in entirely new form, with extensive use of laboratory illustrations.

The plan followed in the editing of the book should be of particular value to the student. A bibliographic reference list is given at the end of each section. A complete index of the volume is included.

RENTGENODIAGNOSTICA POVREJDENIY KOSTEY I SUSTAVOV (The Roentgenographic Diagnosis of Bone and Joint Injuries). G. A. Zedgenidze. Moscow, Medgiz, 1943.

The book contains 315 pages, of which ninety-four pages, at the end of the book, represent a small atlas of illustrations. The introductory part considers the general problems of x-ray examination in traumatic injuries of bones and joints, normal and injured bone in the process of regeneration, peculiarities of fractures in children and in old people, general technique, and especially x-ray examinations in circumstances of war.

The second part of the book describes the roentgenographic diagnosis according to regions of the skeleton. The book is written in Russian.

The whole subject is treated concisely and, despite the comparatively small size, is well balanced. The illustrations are fairly well reproduced.

TEXTBOOK OF SURGICAL TREATMENT INCLUDING OPERATIVE SURGERY. C. F. W. Illingworth, M.D., Ch.M., F.R.C.S.E., Editor. Ed. 2. Baltimore, The Williams and Wilkins Company, 1944. $9.00.

Throughout the book, emphasis is laid on the preoperative and postoperative care of the patient, as being as important as the operative treatment.

This second edition contains a newly written chapter on "The Treatment of Burns".

Affections of blood vessels, skull and brain, spine and spinal cord, peripheral nerves, bones and joints are considered by systems and in later chapters they are taken up by regions. Amputations, fractures, tuberculosis of bones and joints are discussed in special chapters. The subject matter is well presented and well illustrated. The latest methods of treatment are well summarized.

The various chapters have been written by different surgeons. Each one has presented his own personal ideas, and it is surprising that the editor has accepted some of them. In writing of the treatment of cancer of the breast, the statement is made: "Since recurrence of carcinoma in the skin can readily be prevented by X-ray therapy, it is no longer customary to remove a large ellipse of skin and consequently difficulty in closing the wound is rare". The reviewer suggests that, at least in the United States, this is untrue, and that it is vicious teaching. If British x-ray therapy is so efficient, why should not the timid surgeon forego operating at all, and let the radiologist treat the patient?

TRATAMIENTO DE LOS TRAUMATISMOS DEL CARPO (FRACTURAS Y LUXACIONES) [Treatment of Carpal Traumatisms—Fractures and Dislocations.] José A. Sgrosso. Buenos Aires, Aniceto Lopez, 1944.

This booklet of slightly over one hundred pages is based upon the author's observations of 228 cases of injury to the carpus. The work is divided into two main portions. The first deals briefly with the anatomy, the physiology, and the radiology of the bones of the carpus. In discussing the physiology of the wrist, the movements of each of the carpal bones in the various wrist motions are described. Attention is called to the fact that the scaphoid is an intrinsic part of both rows of carpal bones, and that its proximal portion governs the proximal carpal row, and its distal portion, the second row of bones. In discussing radiology, the author stresses the desirability of taking other than the standard anteroposterior and lateral views. The oblique view, with the wrist in 45 degrees of supination, is especially valuable for examining the pisiform and cuneiform bones and the unciform process. The oblique view, with the wrist in 45 degrees of pronation, is valuable for study of the scaphoid.

The second and larger part of the work is dedicated to a rapid review of the fractures and dislocations of the various bones of the carpus. In this recital, lesions of the scaphoid and the perilunar dislocations are naturally given the most consideration. In general, the author's practice seems to be dominated by the reports of American and French surgeons which have already been published.

Unfortunately, little attention is paid to the malaciae, osteoporoses, and other sequelae of injuries of the carpus.

The volume serves a useful function in affording a quick and an accurate review of the subject with a fairly satisfactory bibliography for those who wish to pursue the subject further.

KLINIKA SEPTICHESKICH OSLOJNENIY OGNESTRELNIKH RAN (The Clinic of Septic Complications of Shotgun Wounds). A. V. Melnikov. Moscow, Medgiz, 1943.

The book is written in Russian. It is divided into two parts. The first is dedicated to general pathology, classification, and diagnosis. The second section is devoted to specific problems in the clinical course in definite regions, and to treatment.

The book is of interest, as it apparently presents an approach to the problem of septic infections, used by a large group of surgeons in the U.S.S.R., and especially by the author.

CAMPING FOR CRIPPLED CHILDREN. Edited by Harry H. Howett. Elyria, Ohio, The National Society for Crippled Children and Adults, Incorporated, 1945.

This small volume encourages the universal hope that one day *all* physically handicapped children will have the same rights and privileges enjoyed by physically sound children. Although the struggle is a hard one, and the odds are great, the Society's records show that the camp movement has grown from five camps serving 200 children in 1920, to fifty-six camps serving 3,518 children in 1944.

The National Society for Crippled Children and Adults, recognizing the benefits to be gained by children in summer camps, feels that the special needs of handicapped children can best be met in camps devoted entirely to them. The Society's aims and objectives are clearly set forth. From the choice of a camp site to the careful selection of therapists and technicians, every effort is directed toward helping the crippled child to feel at home in a natural atmosphere, with not the slightest hint of hospital or institution. Stress is laid on a normal life of out-of-door fun, social adjustment, and development of character.

Plans for organization of such camps are set forth in complete detail, and to each chapter there is appended a bibliography for the reader seeking more specific information.

MEDICAL USES OF SOAP. A SYMPOSIUM. Edited by Morris Fishbein, M.D. Philadelphia, J. B. Lippincott Company, 1945. $3.00.

This symposium of articles about soap discusses soap technology, including the chemistry of soap, its manufacture, the new detergents, and detergency or cleansing action; the usual or normal effects of soap on the "normal" skin; its unusual or abnormal effects on the "normal" skin; the effects of soap on the abnormal or diseased skin; its effects on the hair; soaps for industry and the industrial worker; soap for shaving; cutaneous detergents other than soap; and the medical uses of soap.

Nine authors besides Dr. Fishbein have contributed to this symposium. Bibliographies are given for further study concerning the effects of soap on the abnormal or diseased skin; soap for shaving; cutaneous detergents other than soap; and the medical uses of soap.

AMERICAN MEDICAL PRACTICE IN THE PERSPECTIVES OF A CENTURY. Studies of the New York Academy of Medicine, Committee on Medicine and the Changing Order. Bernhard J. Stern, Ph.D. New York, The Commonwealth Fund, 1945. $1.50.

The author discusses the change within a century from a rural to a predominantly urban society, with its concomitant luxuries and conveniences, and what it has meant to medical practice. He contrasts the aids to diagnosis and treatment available to the physician today with the meager equipment of the doctor of the nineteenth century. The gradual growth of medical practice during this period is traced.

Some of the problems considered include the position of the specialist in medicine and that of the general practitioner; trends in the supply and distribution of physicians; the patient load in medical practice; the income of physicians; the distribution of medical services; and the effect of recruiting on the supply of physicians in civilian areas.

This short survey gives many useful statistics and should prove interesting to the reader who wishes a comprehensive picture of the present field of medical practice.

ÜBER MENISCUSGANGLIEN (Cysts of the Menisci). Helge Sjövall. *Acta Chirurgica Scandinavica*, LXXXVII, 561, 1942.

The writer collected twelve cases of cysts of the menisci over a twenty-year period. In ten cases the diagnosis was verified by operation. Seven were in males and five in females. The ages varied from five to sixty-seven. In five cases, the lesion was of the medial, and in seven, of the lateral meniscus. In addition, the writer collected 358 cases from the literature.

From the combined material, he concludes that the lesion is a hyperplastic formation, caused by minor injuries or normal wear and tear of the cartilage tissue. The results with operative removal of the cyst and the cartilage were good. In some of the patients, only the cyst was removed, and these cases were symptom-free at the time of the follow-up examination.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

STUDIES ON RECONSTRUCTIVE AND STABILIZING OPERATIONS ON THE SKELETON OF THE FOOT WITH SPECIAL REFERENCE TO SUBASTRAGALAR ARTHRODESIS IN THE TREATMENT OF FOOT DEFORMITIES FOLLOWING INFANTILE PARALYSIS. Snorri Hellgrímsson. *Acta Chirurgica Scandinavica,* LXXXVIII, Supplementum 78, 1943.

In order to determine the effect of different stabilizing and reconstructive operations on the foot in the treatment of foot deformities resulting from infantile paralysis, and of congenital club-foot in adults, all the traceable patients were subjected to follow-up examinations. These patients had been treated by cuneiform tarsectomy, subastragalar arthrodesis, and panastragalar arthrodesis for these deformities at the Stockholm Orthopaedic Clinic between 1928 and September 1941. Treatment included 100 subastragalar arthrodeses, and fifteen panastragalar arthrodeses for infantile paralysis. There were nineteen congenital club feet treated by subastragalar arthrodeses, and twenty by cuneiform tarsectomy. Thirty-three feet, paralyzed as a result of poliomyelitis, were treated by cuneiform tarsectomy. The results are tabulated.

The results with cuneiform osteotomies were not so good as those obtained with the other operative method, because of recurrence due to incomplete correction of the deformity at the operation. Cuneiform osteotomy is indicated in only the isolated deformity of the mid-foot or forefoot in which muscle balance can be obtained by tendon transplantation. Failures of subastragalar arthrodesis were due to one or more of three factors: incomplete correction of the deformity at the operation; imperfect bone consolidation; and defective stability of the ankle joint.

Out of 100 cases of subastragalar arthrodesis, twenty showed imperfect bony union in one or more joints. In four of these, the deformity had recurred. In one there was severe pain due to the pseudarthrosis between talus and navicular. In the remaining patients a firm fibrous ankylosis had occurred, and the non-union was of no consequence. The three factors of most importance in obtaining bone fusion are: adequate age of the patient; the operative technique; and the duration of the effective immobilization. Arthrodesis should not be performed on a patient under eight years of age, and the writer recommends postponing it until the age of fourteen, if possible. The operative technique should include the removal of all cartilage and compact bone, so that good contact is obtained between spongy bone surfaces. Any gap should be filled with bone chips. Immobilization should be continued for ten weeks or more. Of forty feet immobilized for eight weeks or less, 47.5 per cent. had incomplete bony consolidation. Out of ninety-one feet immobilized for ten weeks or longer, there were only 7.7 per cent. with imperfect fusion. If roentgenograms fail to show union at the end of the period of immobilization, immobilization should be extended for another month.

Panastragalar arthrodesis is indicated when there is, in addition to the indication for subastragalar arthrodesis: (1) marked lateral instability of the ankle, (2) degenerative arthrosis of the ankle joint, or (3) irremediable paralysis of the quadriceps femoris combined with paralysis of the foot. The writer prefers the lateral approach of Guildal which is presented in detail. The foot should be placed in 15 to 20 degrees of equinus in most cases. End results of fifteen cases of panastragalar arthrodesis are carefully analyzed. Eight were good and seven, improved. Three, with tender calluses on the balls of the feet, showed malposition.

This monograph on stabilizing operations is notable also for its historical review, its consideration of foot mechanics and anatomy, the bibliography, and the splendid translation into English by Grace Lundberg. It should be studied by every young orthopaedic surgeon.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

NAILING IN THE MARROW CAVITY IN CASES OF RECENT FRACTURE AND PSEUDARTHROSIS. Anders Westerborn. *Acta Chirurgica Scandinavica,* XC, 89, 1944.

In 1940, Küntscher first publicly presented his method of fracture fixation with a medullary pin, V-shaped in cross section. Since then, the method has been widely used in Germany. The writer presents the results in twenty-eight cases with fourteen fresh fractures and fourteen non-unions. The latter were mostly from gunshot wounds in Finnish soldiers.

The principle of the method is that of firm internal fixation, following reduction by either open or closed methods of the transverse, spiral, or oblique fractures of long bones. The nail is driven in from an incision far from the site of the fracture. Because the nail is V-shaped, it produces firm fixation without occupying much of the marrow cavity. Several sizes are necessary. In the case of the femur, the nail is inserted through the greater trochanter without further preparation of the cortex. For other long bones it is necessary to make a suitable hole. The writer suggested preliminary insertion of a Kirschner wire as a guide.

In the German literature the writer finds widely divergent opinions as to indications. Most surgeons, including Böhler, agree that the method was useful in gunshot fractures of the long bones. A few were enthusiastic about the use of the method in most fresh fractures particularly in older people, in whom it permits early ambulation.

The writer reports the best results in fractures of the femur. Here the method offers the greatest

benefit. Difficulties were encountered in fractures of the tibia. In the forearm, when the radius was nailed, it was still necessary to apply a plaster cast. Westerborn lists the advantages of nailing in the marrow cavity:

1. Shortened stay in bed;
2. Simplified treatment—no extension;
3. Reduced pain and other subjective troubles;
4. Less risk of stiff joints, muscular atrophy, and circulatory disorder;
5. No postoperative physical therapy;
6. Shorter hospital stay and probable earlier return to work.

The risks are recognized. Two cases of fat embolism have been reported. The likelihood is not great. There is apparently no significant damage to the bone marrow. It is recommended that the nail be removed, when the fracture has healed. Osteitis has developed in some cases, but it has not been serious.

Twelve cases of non-union treated by freshening of the bone ends and intramedullary nailing are reported in detail. The results were apparently excellent. Early weight-bearing was possible in most cases.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

A Contribution to the Pathogenesis of Chondromalacia of the Patella. Carl Hirsch. *Acta Chirurgica Scandinavica,* XC, Supplementum 83, 1944.

It is interesting to note that most of our recent knowledge of chondromalacia of the patella has come from the Scandinavian countries. Now comes a study of the pathogenesis from a physical, histological, and chemical standpoint. After exacting studies of postmortem and operative material, the writer decides that a nutritional disorder from unfavorable pressure may be one of the main reasons for pathological changes in the cartilage of the patella.

By using autopsy material and an elastometer which he constructed himself, the writer measured the elasticity of the hyaline articular cartilage of the knee joint in different regions. He showed that:

1. Healthy hyaline articular cartilage had a typical elasticity curve.
2. The degree of deformity occurring in healthy cartilage was dependent upon the pressure per unit area and the duration of the loading.
3. Within certain limits, loads of short duration caused no deterioration in the elasticity, but repeated or prolonged loading produced at least a temporary impairment in elasticity.
4. Cartilage could adapt itself functionally to a certain extent to increasing loads of short duration, in that the relative elasticity modulus computed by the author increased with increases in the loads.

Specimens obtained from autopsy and operation were stained with toluidine blue after fixation in basic lead acetate. Healthy patellar cartilage showed variations in the metachromatic staining in the most superficial zones of the cartilage. Malacic cartilage showed distinctly less metachromatic staining in all the zones. Histologically, the latter exhibited a markedly reduced content of chondroitin-sulphuric acid as compared with healthy patellar cartilage. There is always less chondroitin-sulphuric acid in the superficial than in the deeper layers of the cartilage.

By chemical analysis the author showed that the content of sulphur bound to esters was lower in malacic than in healthy cartilage. Comparative elasticity measurements in healthy and malacic cartilage showed that whenever the content of chondroitin-sulphuric acid was reduced, the cartilage also exhibited impaired elasticity. Loss of elasticity means loss of circulation of the tissue juices and impaired nutrition. If abnormal mechanical strains are often repeated, it is likely that the circulation becomes so impaired that the cartilage grows softer and loses some of its chondroitin-sulphuric acid.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Zur Kenntnis der Skelettveränderungen bei kindlicher akuter Leukose (Information Regarding Skeletal Changes in Acute Leukaemia in Children). Olof Brandberg. *Acta Paediatrica,* XXX, 205, 1942.

Brandberg states the importance of skeletal changes in leukaemia. Chief among such changes are foci of destruction, subperiosteal calcification, and zones of rarefaction. Three case histories are reported in detail. Examination showed that the areas of destruction and the subperiosteal thickening in the bones resulted from leukocytic infiltration. The zones of rarefaction were usually found at the metaphyses, most commonly at the iliac crest and pubic bone. None of these skeletal changes is pathognomonic of leukaemia. They are also commonly found in osteomyelitis and polyarthritis.—*John G. Kuhns, M.D., Boston, Massachusetts.*

Kann de Plattfuss im Kindesalter ohne Einlagen effektiv behandelt werden (Can Flat-Foot in a Child be Effectively Treated without Confining the Child in Bed)? J. Nordenfelt. *Acta Paediatrica,* XXX, 94, 1942.

Nordenfelt states that among children in Sweden flat-foot is an extremely common deformity, and

is frequently the cause of pain and disability. It is a different type of deformity from that found in adolescents. It consists chiefly of a failure or weakness of the ligamentous structures and muscles. Such feet should not be constricted by shoes and stockings. The child should be given an opportunity to strengthen his foot muscles. Forty children were given daily exercises for the feet for from three to nine months. Thirty-one children were considered cured, and the other nine were improved. No foot supports were used. Photographs are shown of ten patients before and after treatment.—*John G. Kuhns, M.D., Boston, Massachusetts.*

BEITRAG ZUR PATHOLOGISCHEN ANATOMIE DER ARACHNODAKTYLIE (Investigation of the Pathological Anatomy of Arachnodactilia). C. G. Bergstrand. *Acta Paediatrica,* XXX, 345, 1943.

Arachnodactilia is a relatively rare condition about which little has been reported. Bergstrand reports the case history and postmortem examination of a female infant suffering from arachnodactilia. Death was due to bronchopneumonia. The only abnormal findings were a single lobe in the left lung and absence of the dilator pupillae in both eyes. Microscopically, no abnormal findings were observed in the bones, connective tissue, musculature, or endocrine glands. In the literature, Dupuytren-like contractures have been reported, and it has been mentioned that the bones grew more rapidly than the connective tissue. After reviewing the theories which have been advanced to explain this deformity, the author concluded that it appeared to be a mesodermal dystrophy.—*John G. Kuhns, M.D., Boston, Massachusetts.*

ISOLIERTE FRACTUREN DER ERSTEN RIPPE (Isolated Fractures of the First Rib). S. E. Sjögren. *Acta Radiologica,* XXIII, 79, 1942.

Five cases of isolated fractures of the rib are reported. In the author's opinion, this fracture is more common than is believed. Because of the difficulty of roentgenographic demonstration, the lesion may be overlooked.

The fracture may arise as a result of: (1) indirect trauma through the clavicle; (2) direct trauma from behind; (3) indirect trauma from the manubrium; (4) contracture of the scalenus muscle.

The clinical symptoms are always indefinite. Usually the patient complains of pain in the shoulder. This is made worse by motion of the head or arm, but not by deep breathing. This fracture may be complicated by injury to the underlying subclavian vessels, the brachial plexus, or the lung. Healing is usual, but pseudoarthroses are occasionally seen.—*Henry Milch, M.D., New York, N. Y.*

ZWEI NEUE FÄLLE MIT "STREIFENFÖRMIGER OSTEOPOIKILIE" (VOORHOEVE) [Two Cases of the Streaky Form of Osteopoikilosis (Voorhoeve)]. Åke Lindbom. *Acta Radiologica,* XXIII, 296, 1942.

Osteopoikilosis is a hereditary skeletal anomaly first described by Albers-Schönberg in 1915. Roentgenographically it appears in two forms, (1) the more common spotty form, and (2) the unusual streaky form described by Voorhoeve in 1924.

The former occurs in the metaphyses and epiphyses of the long bones, the tarsalia, the carpalia, the pelvis, and the shoulder girdle. The latter is found in the metaphyses of the long bones close to the epiphyseal line at points where endochondral ossification occurs.

In addition to the two cases originally described by Voorhoeve, two cases were described by Mascherpa in 1931. Two additional cases are presented by Lindbom. As in the earlier cases, the two here reported occurred in a brother and sister. In both the condition caused no symptoms and was an accidental discovery. In both the skin condition known as dermatofibrosis lenticularis disseminata was present.

The presence of the skin lesion strengthens the belief in relationship between the spotty and streaky forms of osteopoikilosis.—*Henry Milch, M.D., New York, N. Y.*

TUBEROUS SCLEROSIS WITH CHANGES IN LUNG AND BONES. E. Samuelson. *Acta Radiologica,* XXIII, 373, 1942.

The author reports the case of a female aged forty-nine whose clinical course began at the age of thirty-six years with hemoptysis. A diagnosis of mitral stenosis made at this time was later changed to pulmonary tuberculosis, then to chronic miliary tuberculosis, and finally to Boeck's sarcoid. Roentgenographically, the patient presented the signs of bilateral miliary infiltration of the lungs. The hands "showed periosteal thickening on the metacarpal bones and in the fingers, both some opacities and some osteoporosis with cyst-like rarefactions".

In June 1941 the patient died of cerebral hemorrhage and the postmortem examination disclosed: "(1) irregular, nodular, or tuberous sclerosis in the lungs with small-cystic pulmonary degeneration; (2) sequelae after an old endocarditis and a parietal thrombus in the heart; (3) multiple benign tumors in both kidneys; (4) tuberous sclerosis of the brain, two small tumors in the choroid plexus and multiple brain infarcts with hemorrhage and emollition; (5) roentgenographically demonstrable changes in both hands". No signs of tuberculosis or Boeck's sarcoid were found.

Bone changes have been reported in the cranium as well as in the hands and feet. "Whether these changes are possibly due to small fibrous or similar small, benign tumors in the periosteum and bone

marrow is probably not known, inasmuch as it does not seem that any patho-anatomic examination has been made of the hands."

It is the opinion of the author that the tuberous sclerosis of the lungs, bone changes, the tumors of the kidney, and the brain condition are all part of the heterogeneous picture of tuberous sclerosis.—*Henry Milch, M.D., New York, N. Y.*

PRIMARY BONE SARCOMA. Reidar Eker and Erik Poppe. *Acta Radiologica,* XXIII, 387, 1942.

Among 3,795 patients treated for malignancy at the Norwegian Radium Hospital, forty-two suffered from primary sarcomata of bone. These were classified as follows: In the osteogenic series, were eighteen cases of osteoblastic tumors, and four cases of osteolytic tumors; in the chondroma series were seven cases of chondrosarcoma, and three cases of myxochondrosarcoma; there were five cases of Ewing's sarcoma; four cases of periosteal fibrosarcoma; and one case was a non-classifiable sarcoma.

All but one of the patients were given protracted fractioned roentgenotherapy. This consisted of a total of 12,000 to 13,500 roentgen units. In some cases, a second series of half the dosage was given after a lapse of from three to four months.

The authors call attention to the fact that of the twenty-two cases of osteogenic sarcoma, thirteen were localized to the metaphyses around the knee joint. In twelve, there was a history of trauma in the tumor region. These traumata occurred from two weeks to two years before the onset of symptoms. In five cases there was a history of continuous symptoms following injury. Pain is usually the first symptom.

The osteoblastic form occurs mainly in the young-age group; the osteogenic type in the older-age group. In both, the prognosis seems to depend upon the histology of the tumor. "In our opinion combined surgical and radiological treatment should be administered for osteogenic sarcomata. By beginning with radiological treatment a basis can be established for the tumors' radiosensitivity. If the tumor belongs to a type of low histological malignancy, and proves to be rather radiosensitive, there is a possibility that operation may be avoided or carried out with retention of the function of the limb."

In general, the prognosis is not good, although three patients are alive and healthy more than five years after the first treatment. The average length of life is not quite twenty-one months after the first treatment, or a little more than twenty-five months after the onset of symptoms.

Roentgen treatment had little or no effect on the cases of myxochondrosarcoma. In five of six cases of chondrosarcoma, there appeared to be subjective improvement.

Ewing's tumor is extremely sensitive to roentgenotherapy, and the five cases which the authors studied were given roentgen treatment exclusively. Four of the patients died within three to fourteen months after the first treatment. One patient is alive and free from symptoms after five years.

For periosteal fibroblastic sarcoma, surgery is considered the most important form of therapy. Resection of the tumor followed by radiation therapy is a procedure which seems satisfactory.—*Henry Milch, M.D., New York, N. Y.*

VOLUM- UND FORMVARIATIONEN DES WIRBELKANALS BEI LORDOSIERUNG, BZW. KYPHOSIERUNG UND IHRE BEDEUTUNG FÜR DIE MYELOGRAPHISCHE DIAGNOSTIK (Variations in Form and Volume of the Spinal Canal in Lordosis and Kyphosis; Its Significance in Myelographic Diagnosis). Folke Knutsson. *Acta Radiologica,* XXIII, 431, 1942.

Myelographic diagnosis is based upon extradural deformation of the dural sac. The dural sac is separated from the wall of the spinal canal by a slight amount of loose connective tissue, and in consequence its contour is dependent upon the outline of the spinal canal.

In order to determine the influence of each of these elements, the author studied cadaver and living specimens fixed in lordosis and kyphosis. He was able to show that there was a definite decrease in the volume of the canal when the spine assumed the position of lordosis. In this attitude three factors are noted: (1) the ligamenta flava become shorter and thicker, and by bulging into the canal they reduce its volume; (2) the intervertebral notches become smaller because the superior articular facets are rotated forward; and (3) the intervertebral disc bulges backward into the vertebral canal.

Since the nerves course along the anterior wall, they occupy a greater portion of the narrowed (lordotic) spinal canal than of the kyphotic canal. As a consequence the defect in the column of the contrast medium is greater in lordosis than in kyphosis.—*Henry Milch, M.D., New York, N. Y.*

ASEPTIC NECROSES IN THE EPIPHYSES OF DIGITAL PHALANGES AND METACARPAL BONES (THIEMANN'S DISEASE; DIETRICH'S DISEASE). Sigurd Franck. *Acta Radiologica,* XXIII, 449, 1942.

The author presents the case of a young man, eighteen years old, who complained of pains in his fingers. The symptoms had begun three to four years previously, without any history of trauma. Objectively there was slight restriction of mobility with swelling of the affected joints. Roentgenographically there was found flattening, irregular bony sclerosis, cup-shaped broadening of the basal epiphyses, and fragmentation and sequestration in the epiphyses.

The diagnosis is made on the basis of the roentgen changes. When healing occurs, the symptoms recede. Treatment is always symptomatic.

The condition may affect both the phalanges and the metacarpals (described by Thiemann in 1909), or only the metacarpals (described by Dietrich in 1932).—*Henry Milch, M.D., New York, N. Y.*

HEMANGIOMA OF THE CERVICAL VERTEBRA WITH FRACTURE AND COMPRESSION MYELOMALACIA. Olav Holta. *Acta Radiologica,* XXIII, 423, 1942.

Hemangioma of the vertebra occurs in approximately 10 to 12 per cent. of all spines. Schmorl and his associates, examining 2,154 spines, found 257 instances, or 11.93 per cent. Junghanns found 409 hemangiomata in an examination of 3,829 spines. Of these, 350 occurred in the thoracic spine, 170 in the lumbar spine, thirty-two in the cervical, and twenty-seven in the sacral areas. Generally speaking, women are more frequently affected than men, and more than half develop in people under the age of thirty.

The hemangiomata are found mainly in the body of the vertebra, but may affect the arch. Clinically these hemangiomata give rise to symptoms of transverse myelitis when they reach the surface of the bone, and cause a compression of the underlying spinal cord. This may be due to: (1) propagation of the hemangioma into the spinal cord; (2) compression through thickening of the corpus and the arch; (3) compression fracture of the vertebra; (4) epidural hemorrhage.

Roentgenographically these tumors appear as rarefactions of the spongiosa with longitudinal thickening of the trabeculae. In the arches, hemangiomata may present the appearance of an irregular network.

Treatment may be either surgical or by radiation. Where definite compression symptoms exist, laminectomy may alleviate the medullary pressure.

The author reports a case in which a compression fracture of the fourth cervical vertebra, the site of a hemangioma, took place. The patient developed symptoms of a complete transverse lesion at the level of the fourth cervical vertebra, and died despite roentgenotherapy.

Autopsy revealed a typical hemangioma of the fourth cervical vertebra with compression of the body. Examination of the spinal cord disclosed a myelomalacia at the level of the vertebral lesion.—*Henry Milch, M.D., New York, N. Y.*

TWO CASES OF SYMPATHICOBLASTOMA OF THE SUPRARENAL GLAND WITH METASTASES TO THE CRANIUM AND THE TUBULAR BONES. Thomas Rosendal. *Acta Radiologica,* XXIII, 462, 1942.

The author reports two cases of sympathicoblastoma. These tumors usually occur in children below the age of two. They are characterized by metastases to the cranium, especially about the orbits, and are typically associated with exophthalmos and hemorrhages into the eyelids. In the cranium, the metastases show small spotted destruction; in the long bones, they show large spotted destruction.

The cranial changes may resemble Hand-Schüller-Christian syndrome, Ewing's sarcoma, lues, chloroma, and leukaemia. Roentgenotherapy has only a temporary effect. As a rule the lesion is fatal. A single case has been described in which the patient was still alive fifteen years after operation.—*Henry Milch, M.D., New York, N. Y.*

ASEPTIC BONE NECROSIS OF THE OS CAPITATUM (OS MAGNUM). Gunnar Jönsson. *Acta Radiologica,* XXIII, 562, 1942.

The author reports a case of aseptic necrosis of the capitate bone, occurring in a nurse twenty-two years old. There was no previous history of trauma. The patient complained of pain, weakness, and occasional swelling. There were no signs of inflammation, but crepitus was noted on motion of the wrist. The x-ray showed typical progressive fragmentation, sclerosis, and compression of the capitate bone.

It is believed that this hitherto undescribed condition resembles that found in the os lunatum. The process has not become completely quiescent, and ultimately an osteo-arthritis of the wrist may be expected. No indication for therapy is given.—*Henry Milch, M.D., New York, N. Y.*

ROENTGENOLOGICAL EARLY SYMPTOMS AND HEALING PHENOMENA IN CHRONIC RHEUMATIC ARTHRITIS. Folke Knutsson. *Acta Radiologica,* XXIV, 121, 1943.

The author has had the opportunity of studying cases of rheumatoid arthritis over prolonged periods of time. He is of the opinion that early diagnosis can be made roentgenographically from studies of the hands and feet. These two appear to be the sites of predilection in the early phases of the disease.

In this phase the roentgenograms are characterized by articular decalcification, especially in the metatarsophalangeal or metacarpophalangeal joints. Juxta-articular periostitis is quite typical, and is apparently present only in the florid stage of the disease. The author does not believe that increase in width of the joint due to effusion is commonly seen.

On the contrary, narrowing of the joint space as a result of destruction of the cartilage is typical of the second stage. So-called "ulceration" or destruction appears mainly in the head of the fifth metatarsal. Such ulcerations, however, appear elsewhere.

The third or healing stage is characterized by replacement of the irregular contour of the ulcerations by a smooth, even outline. In those cases in which the cartilage has disappeared entirely, fusion of the joint takes place. The author suggests that in evaluating the effects of therapy, the roentgenographic changes should be noted.—*Henry Milch, M.D., New York, N. Y.*

SOME EXPERIENCES WITH A NEW METHOD OF ARTHROGRAPHY. Kjeld Andersen. *Acta Radiologica,* XXV, 33, 1944.

The author comments upon the difficulty of obtaining satisfactory arthrograms in conditions affecting the menisci. In the method which he recommends, N_2O is used as a contrast medium. After appropriate sterilization, the skin is anaesthetized with five cubic centimeters of 0.5 per cent. novocaine. Using the technique and instrumentarium of Tischendorff sixty to one hundred cubic centimeters of N_2O is injected into the knee joint.

The patient is then placed in the prone position, and the knee is flexed, abducted, or adducted until optimum views as determined by the fluoroscope are achieved. Eight to ten roentgenograms are made in different positions. The method has been used in fifty-two cases. The roentgenograms which are reproduced are really so clear that even untrained observers can recognize the lesion. The method seems worthy of trial.—*Henry Milch, M.D., New York, N. Y.*

COMMON CONGENITAL ANOMALIES OF THE BONY THORAX. L. K. Sycamore. *The American Journal of Roentgenology and Radium Therapy,* LI, 593, 1944.

The author studied chest roentgenograms of 2,000 freshmen entering Dartmouth College. Congenital anomalies of the bony thorax occurred in 2.8 per cent. of the students. There were twenty cases of bifurcation of the ribs, ten cervical ribs, ten rudimentary first ribs, six cases showing flaring of the anterior end of the rib, six cases where two ribs were fused, and four cases where there was bridging between two ribs. Calcification of the first costal cartilage was found in 4 per cent. of the college freshmen, who averaged nineteen or twenty years of age, but a series of 100 roentgenograms of medical students three or four years older showed calcification in a greater or lesser degree in 42 per cent.

Evidence is presented which suggests that the appearance, described by various authors as fracture of the first rib, may in some cases be due to a congenital anomaly.—*E. A. Cobb, M.D., Iowa City, Iowa.*

OSTEOCHONDRITIS OF THE CAPITELLUM (PANNER'S DISEASE). Herman C. March. *The American Journal of Roentgenology and Radium Therapy,* LI, 682, 1944.

The author reviews the literature concerning osteochondritis of the capitellum and finds that, since Panner first described this site of osteochondritis, very few cases have been presented. He presents one case. Good roentgenograms accompany the case history.—*E. A. Cobb, M.D., Iowa City, Iowa.*

TRAUMATIC SEPARATION OF THE UPPER FEMORAL EPIPHYSIS. A BIRTH INJURY. Putnam C. Kennedy. *The American Journal of Roentgenology and Radium Therapy,* LI, 707, 1944.

The author reviews from the literature twenty cases of traumatic separation of the upper femoral epiphysis, and adds one case of his own. Every case except one in the literature occurred during podalic version and breech extraction, or breech presentation and extraction. In the author's case, the position was occipitoposterior, delivery was by low forceps, and no known trauma was exerted on the legs. The author states that at birth the upper femoral epiphysis is a single cartilaginous mass, including head, neck, and both trochanters. In traumatic separation, it is displaced medially and downward at its junction with the diaphysis. The periosteum is usually stripped up and sometimes ruptured. The joint capsule and ligamentum teres femoris remain intact. Rotary movements combined with traction on the leg are necessary to produce the injury. The clinical signs are swelling, slight shortening, limitation of active motion, painful passive motion, and external rotation; and occasionally discoloration, crepitus, abduction or adduction.

The roentgenographic signs are displacement of the proximal end of the diaphysis, upward and outward; rapid, profuse callus formation and prominent subperiosteal reaction around the upper end of the shaft; absorption of callus and reconstruction of the femoral neck; and premature ossification of the capital epiphysis and accelerated growth of the femoral neck on the injured side.

The prognosis is good in cases of milder injury, but rather poor when the initial trauma and displacement have been severe. Coxa vara is a frequent end result in the latter group of cases.—*E. A. Cobb, M.D., Iowa City, Iowa.*

PRIMARY HEMANGIOMATOUS TUMORS OF SKELETAL MUSCLE. Thomas A. Shallow, Sherman A. Eger, and Frederick B. Wagner, Jr. *Annals of Surgery,* CXIX, 700, 1944.

This is an extensive and complete article dealing with the subject of primary hemangiomatous tumors of skeletal muscle. The authors make an analytic review of 333 cases in the literature and add two cases of their own.

The practical conclusions of the study of these tumors are as follows:

1. The lesion is of the diffuse type in most cases.

2. There are no proved cases of metastasis from a primary muscle hemangioma, although malignant degeneration has been reported as probable in a few instances.

3. In treatment the procedure of choice is early complete surgical excision, well beyond the confines of the tumor. This was the treatment used in 79 per cent. of the cases, with improvement or cure in 90 per cent. If malignant degeneration is suspected, deep postoperative roentgenotherapy is advocated.

4. There was no surgical mortality for the entire series. Local recurrence or lack of improvement was reported in 6 per cent. Postoperative deformity resulted in 4 per cent.

The authors favor the view that hemangiomata are congenital tumors, originating from abnormal embryonic sequestrations of vascular tissue. Trauma and systemic infection, acting as secondary factors, may modify subsequent growth and clinical manifestations.—*Jose Puig Guri, M.D., Iowa City, Iowa.*

A Physiologic Analysis of the Nature and of the Treatment of Burns. William W. L. Glenn. *Annals of Surgery,* CXIX, 801, 1944.

Attention is directed to this article because of its possible importance with regard to the exudate which forms in the soft tissues in fractures. In burns it was found that the exudate clotted and formed a stagnant gel which acted as a foreign body. This gel was slowly absorbed, and its complete removal was necessary before healing took place. It formed a source of nitrogen for the proliferation of fibroblasts with ultimate scarring. For these reasons, it was decided that restriction of the exudate is imperative in all burns. Perhaps further study of this subject will show an analogy or even a similarity between the gel which forms in burns and the state of the exudate which forms in fractures. If this is demonstrated, there will be good reason for attempting to limit the exudate in fractures even as in burns.

Glenn found that closed plaster encasements, gently molded over a minimum of gauze padding, and extending entirely over the end of the extremity, were effective in restricting the exudate. No local harm resulted from this treatment. It is strongly emphasized that no external pressure is used in applying the plaster. As plasma escapes from the dilated capillaries, the pressure which the extravascular tissue fluid builds up against the plaster encasement is exactly equal to the pressure attempting to push fluid out of the capillaries. When this pressure equilibrium is reached, no more fluid can leak out than can be carried off by the lymphatics or can be absorbed by the capillaries.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

External Pin Transfixion of Fractures. An Analysis of Eighty Cases. Irwin E. Siris. *Annals of Surgery,* CXX, 911, 1944.

In view of the enthusiastic reception given to the various ingenious devices which make it not only possible but tempting to employ external pin fixation in the reduction and immobilization of fractures, this paper sounds a timely note of warning. This warning is all the more insistent, since it comes from the teaching department of a large metropolitan hospital.

On the basis of a careful analysis of the results in eighty cases treated by external pin fixation, it is concluded that the method should not be used routinely, but should be restricted to selected cases, and then should be employed only by surgeons trained in the technique. The reasons for these conclusions lie in the reported results: discharge from the pin sites in thirty-seven out of eighty cases; osteomyelitis at the pin sites, with discharge persisting long after the fracture had united in eighteen cases; death in eight cases. Delay in union was more common, and seemed to result from the frequent distraction of the fragments.

It is believed that the use of external pin fixation is desirable in persistently displaced compound fractures, and in certain problem fractures. But it is also the author's belief that too much emphasis has been given to the desirability of ambulation, and to constant joint motion; neither of these is an adequate reason for the general employment of external pin fixation.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

Fascial Slinging of the Scapula and Clavicle for Dropped Shoulder and Winged Scapula. G. C. Dorling. *The British Journal of Surgery,* XXXII, 311, 1944.

The first patient suffered from a winging of the right scapula. This injury followed artificial respiration, given during an operation when he stopped breathing. Two attempts to repair the damaged long thoracic nerve had been made without success.

Very ingenious fascial slings were made, which suspended the scapula to the spinous processes of the sixth cervical and the third thoracic vertebrae. The approach was made by an incision from the fifth cervical to the fifth thoracic vertebrae, just to the left of the midline. A large skin flap was turned back. Holes were bored in the scapula half way between its spine and the upper border, and strips of fascia were threaded

through and carried over the spinous processes. An abduction plaster was applied, and the patient now suffers no disability. He is at present a physical-training instructor.

The second patient was a woman of forty-four who suffered a paralysis of the spinal accessory nerve during an operation for tuberculous glands of the neck. Two previous operations had been only partly successful. Due to paralysis of the trapezius muscle the entire shoulder girdle drooped. The author suspended the scapula from the sixth cervical vertebra by a fascial strip with very gratifying results.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

THE PROBLEMS AND PRINCIPLES OF THE RESTORATION OF LIMB FUNCTION FOLLOWING INJURY, AS DEMONSTRATED BY HUMERAL SHAFT FRACTURES. F. S. A. Doran. *The British Journal of Surgery*, XXXI, 351, 1944.

The cause of joint stiffness may be articular in origin, in which case it may be due to a bony obstruction caused by the displacement of the articular elements, or to shortening of the capsule, possibly with the formation of inelastic pericapsular fibrous adhesions. The cause of the stiffness may be muscular in origin. This may be due to lack of power to contract because of intramuscular fibrosis, to binding of the muscle to the bone by scar tissue, to gross destruction of muscle tissue, or to paralysis of the motor nerve.

Fractures from flying accidents are usually comminuted. They are slower to unite, and give more joint stiffness than those caused in accidents from other causes. The results in the latter group are twice as good as in the former. The amount of joint disability depends on the site of fracture as well as on the mode of injury.

In this group of seventy-six cases of fracture of the humeral shaft, all patients who regained full elbow movement did so in eight weeks or less.

The writer accepts the Roux theory that more vigorous exercise not only alters the qualitative composition of the muscle, thereby raising its specific efficiency, but also enlarges the muscle in those dimensions only which yield greater activity to the given function. He, therefore, advocates the early use of Swedish resistance exercises to restore power and joint mobility, and the later use of the Danish type of exercise to give speed and coordination.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

THE RESULT OF OPERATIVE REPAIR OF SEVERE ACROMIO-CLAVICULAR DISLOCATION. A. N. Birkett. *The British Journal of Surgery*, XXXII, 103, 1944.

This is the record of a man of twenty-nine, injured by being crushed between two lorries. Roentgenograms showed wide separation of the acromioclavicular joint, and it was believed that the outer end of the clavicle was buried in the trapezius. Closed reposition was impossible.

Open operation was carried out, and the dislocation was reduced. A strip of fascia lata was passed through a hole bored in the clavicle, under the coracoid, over the clavicle, through a second hole near the acromioclavicular joint, and out through a third hole in the acromion. The two ends of the fascial strip were sutured on the upper surface of the clavicle.

Roentgenograms showed a mild degree of subluxation still present. Recovery was rapid. Check-up roentgenograms showed calcification along the fascial tracts between the coracoid and the clavicle. There was some restriction of motion.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

AN UNUSUAL DISLOCATION OF THE FOOT. E. W. Dorrell. *British Medical Journal*, II, 12, 1944.

The author reports an uncommon dislocation of the foot, sustained when the front wheel of a gun-trailer slowly rolled backward over the patient's left foot, from the medial to the lateral side.

Roentgenograms showed the cuboid and cuneiforms had been squashed together, and the base of the second metatarsal forced out of its mortise. The metatarsals had been forced laterally, the fifth completely dislocated, the second, third, and fourth being subluxated laterally to a lesser degree. The cuneiform clinically was very prominent on the medial side of the foot.

Reduction was accomplished, under anaesthesia, without traction, by pressure medially on the base of the fifth metatarsal, and laterally on the first cuneiform. A surface wound on the anteromedial side of the foot was sutured, and a short unpadded leg plaster applied. After twelve days, this plaster was replaced by another for a period of four weeks. A walking-iron was then used, and weight-bearing was allowed. After eight weeks from the date of injury, the plaster was removed altogether. Now, three months after the accident, the patient is walking, and has full painless movement at the ankle joint; inversion and eversion are almost normal.

FRACTURES OF THE WRIST AND HAND. H. S. Morton. *The Canadian Medical Association Journal*, LI, 430, 1944.

The author reviews thirty-two cases of fracture of the carpal scaphoid. In twenty-three, the injury resulted from a fall.

Treatment consisted of immobilization in a cast, incorporating the joints above and below the injury, for three or four months. Firm union resulted in nineteen cases. Bone-grafting was used in ten

fractures that failed to unite. A bone graft, one-quarter of an inch in diameter, united the fragments in nine of the ten cases. The author advises against whole or partial excision of the scaphoid, because of resulting residual pain and loss of power. In one case, where drilling and partial excision were used, nonunion of eighteen months' duration occurred.

In the treatment of fractures of the metacarpals, two methods were employed: (1) the use of the femoral bone clamp for reduction, and (2) a trapezium fixation by transverse pins, using the adjacent metacarpal as the fourth side of the geometrical figure.

In compound fractures of the phalanges, careful reduction and early movement are invaluable. Longitudinal pinning, by means of an intramedullary wire, was used successfully by the author.

THE OPERATIVE TREATMENT OF INJURIES TO THE SEMILUNAR CARTILAGES IN PERSONNEL OF THE BRITISH AIR FORCES. D. M. Meekison. *The Canadian Medical Association Journal*, LI, 517, 1944.

The author discusses the importance, in the operative treatment of injuries to the semilunar cartilages (menisci) of the knee joint, of (1) correct diagnosis, (2) absence of arthritic changes, (3) the age of the patient, and (4) the adequate and rapid removal of the torn meniscus.

In examining a knee joint for internal derangement, the author looks for the presence of atrophy of the thigh; the presence or absence of fluid in the joint, and of local heat on palpation; springy resistance at 20 or 15 degrees from complete extension (suggestive of a complete bucket-handle lesion); stability of the collateral ligaments tested in extension, and of the cruciates tested at about 100 degrees; points of tenderness around the joint line, and at the attachments of the collateral ligaments with the knee at 90 and 100 degrees; and evidence of posterior herniation in the popliteal space.

The prognosis is poor where arthritis is present in the knee joint, or if the patient is not young. The author avoids operation in a patient over the age of forty, or at most forty-five.

At operation, the incision is well out from the patella, bordering on the tibial collateral ligament. The fascia and the capsule are separated, are incised separately, and the joint is opened from above downward. All articular surfaces are examined carefully. The whole cartilage is removed. If necessary, a posterior incision is made to obtain the posterior horn. The capsule is lightly tacked with interrupted catgut, allowing any effusion to leak through the capsule and be absorbed.

The postoperative dressing includes cotton wool wrapped around the joint, and two elastic bandages, the second a compression bandage, to be removed twenty-four hours later. The patient is allowed up after ten days. Quadriceps exercises are carried out before and after the operation. Results are excellent in nine out of ten cases.

Although final end-result figures have not been obtained by the author, a general and informal survey of some thousands of cases produced a figure of 93 per cent. returned to full duty after seven weeks.

INFECCIONES AGUDAS DE LA MANO (ACUTE INFECTIONS OF THE HAND). Luis Raul Flores. *Cirugia y Cirujanos*, XII, 209, 1944.

This is a long and detailed article dealing with the subject of hand infections, and emphasizing the importance of taking such infections seriously. The author has followed the ideas of Kanavel and Koch, and he feels that surgery performed on the hand should be treated as major surgery, frequently requiring more judgment than abdominal surgery. Only a surgeon of experience should treat infections of the hand. The article points out that the hand has six major spaces where pus can accumulate: dorsal subcutaneous, dorsal subaponeurotic, hypothenar, thenar, interdigital, and mid-palmar. The direction of travel of infections of the various fingers is described. There are two main soft-tissue infections in the hand: lymphangitis and tendon-sheath infections. The generalized nature of the swelling and lack of point tenderness are characteristic of lymphangitis. Tenosynovitis shows exquisite point tenderness, flexion of the finger, pain on extension, and a diffuse swelling involving the finger only. The importance of correct incisions in infections of the hand is stressed. The entire subject is well and accurately covered in this article, which is profusely illustrated. — *Major Louis W. Breck, M.C., Camp Swift, Texas.*

THE SIGNIFICANCE OF MUSCLE SPASM IN THE ACUTE STAGE OF INFANTILE PARALYSIS BASED ON ACTION CURRENT RECORDS. R. Plato Schwartz, Harry D. Bouman, and Wilbur K. Smith. *The Journal of the American Medical Association*, CXXVI, 695, 1944.

After establishing the firm foundations upon which rests the so-called orthodox concept of infantile paralysis, and quoting from the originator of the "new Kenny" concept, the authors again investigated the characteristics in the neuromuscular mechanism in the acute stage of infantile paralysis, in normal individuals and in patients with spastic paralysis. They paid particular attention to muscle spasm. From their data the following points were established:

"1. In some patients spasticity has been recorded in all muscles . . . investigated.

"2. Evidence of spasticity has been recorded from (a) weakened muscles, (b) the antagonists of weakened muscles and (c) muscles which exhibit no clinical or other evidence of weakness.

"3. The evidence does not support the view that fibrillation or inflammation of the muscle is responsible for the spasticity.

"4. On stretching the antagonist of a weakened muscle, the evidence of spasticity in the weakened muscle is frequently greater than the recorded reaction of the muscle in response to voluntary contraction.

"5. On stretch reflex of a weakened muscle, spasticity not only is recorded from its antagonist but also is significantly present in records of the corresponding muscles of the opposite extremity.

"6. In association with voluntary contraction efforts this spasticity spread was recorded from the same group of muscles as resulted from stimulation by stretch reflex noted in 5.

"7. But a muscle which shows no clinical evidence of weakness always produces a stronger voluntary contraction record than the recorded evidence of muscle spasm.

"8. There has never been recorded evidence of spasm when a muscle failed to produce a record of reaction to the voluntary movement.

"9. Spasticity is a generalized phenomenon in the early stages of infantile paralysis.

"10. As prevailing spasm diminished in a weakened muscle, there was recorded evidence of increased strength in the voluntary contraction.

"11. The gross initial spasm of neck and back muscles, so characteristic with onset of the acute stage, invariably disappears without evidence of muscle weakness or paralysis.

"12. There was no correlation between the degree of spasm and the incidence of muscle weakness or paralysis."

In summary of their discussion, the authors state that "certain functional abnormalities other than muscle weakness were observed in the lower reflex arc. They could be most readily explained in terms of a dysfunction at or proximal to the dendrites or cell body of the lower motor neuron. This dysfunction resulted in a partial isolation of the lower motor neuron from the inhibition normally induced by other levels through long and short neural pathways. The degree of lower reflex arc isolation thus established and the degree of viability remaining in the lower motor neurons therefore determined the amount of muscle spasm in each instance.

"Without the involvement of levels proximal to the lower motor neuron there would be no spasm, but the muscle could be either weak or normal, dependent on the number of normal motor neurons innervating the muscle.

"If all motor neurons failed to be stimulated by the stretch reflex there would be no reaction to the stretch reflex even though relationships proximal to the dendrites were normal.

"Spasticity and weakening are two separate phenomena, each dependent on specific disturbances of functions of the anterior horn cells.

"There was every indication that spasm ran its course like other clinical manifestations of the disease.

"The relationship between muscle tenderness and muscle spasm has not been clarified by the work thus far done. . . .

"We have emphasized the clinical phenomena and the electromyographic evidence which indicates that muscle spasm does not initiate the development of muscle weakness."

This article is well organized and is worthy of careful and repeated study by all orthopaedic surgeons interested in anterior poliomyelitis. — *Brandon Carrell, M.D., Dallas, Texas.*

THE ROENTGENOLOGY OF OSTEOMYELITIS. J. W. Pierson and J. F. Roach. *The Journal of the American Medical Association,* CXXVI, 884, 1944.

The authors summarize in a concise fashion the present knowledge of the pathology and associated roentgenographic findings of acute and chronic osteomyelitis. From a roentgenographic point of view, there are three groups of diseases which frequently cause differential difficulties: (1) other infections; (2) bone tumors; and (3) diseases of the reticulo-endothelial system. Syphilis and tuberculosis of the long bones are the two most troublesome infections, and often they cannot be differentiated without additional clinical information. Especially difficult is the differential diagnosis of such bone tumors as osteogenic sarcoma, Ewing's endothelioma, and the metastasis of neuroblastoma. The diseases of the reticulo-endothelial system which cause difficulty are the leukaemias, the lymphomata, the xanthomata, and the congenital anaemias. The characteristic roentgenographic picture of any one of these diseases is usually readily differentiated from the others and from osteomyelitis, but each may have a stage in its development when one sees the picture of osteomyelitis. — *H. H. Beckering, M.D., Dallas, Texas.*

PERSISTENCE OF VIRUS EXCRETION IN THE STOOLS OF POLIOMYELITIS PATIENTS. Dorothy M. Horstmann, Robert Ward, and Joseph L. Melnick. *The Journal of the American Medical Association,* CXXVI, 1061, 1944.

The authors undertook a study to determine the average duration of excretion of poliomyelitis virus in stools of patients following acute infection, and to ascertain whether a chronic carrier state similar to

that occurring in typhoid exists in poliomyelitis. After studying the excretion of poliomyelitis virus in the stools of sixty-one patients, it was found that in sixty-one per cent. the virus was excreted during the first two weeks after onset of the disease, in 50 per cent. during the third and fourth weeks, in 27 per cent. at the fifth and sixth weeks, and in 12.5 per cent. at the seventh and eighth weeks. After the ninth week, virus was detected in only one of fifty-two specimens tested; this had been excreted in the twelfth week. Not one of the sixty-one patients followed was demonstrated to have become a persistent carrier of poliomyelitis virus.—*Brandon Carrell, M.D., Dallas, Texas.*

PNEUMOCOCCIC ARTHRITIS. REPORT OF CASE OF SO-CALLED PRIMARY PNEUMOCOCCIC ARTHRITIS. William P. Boger. *The Journal of the American Medical Association,* CXXVI, 1062, 1944.

The author regards pneumococcic arthritis as a manifestation of a septicaemia, even in those cases in which the primary focus from which the organism gained access to the blood stream cannot be determined. He has thoroughly reviewed and brought up to date the literature of this rare disease, and adds one case of his own, in which the causative organism was Type XII pneumococcus. Purulent exudate, aspirated five days after adequate sulfadiazine therapy, again yielded this type of organism in pure culture. The incidence of pneumococcic arthritis as a complication of pneumonia is given as 0.3 per cent. Seventy to 75 per cent. of the cases of pneumococcic arthritis occur in association with pneumonia.

The usual clinical features of an acute pyogenic arthritis are seen in this disease, and the following are regarded as almost pathognomonic: white, periarticular oedema, with prominent venous collateral circulation; elevated temperature with the patient in good general condition; the absence of regional lymphadenopathy; and the rapidity of reappearance of swelling of the joint after aspiration. The disease is monarticular in about 75 per cent. of the cases.

Recommended treatment is similar to that for the usual pyogenic arthritides, but the observation made in 1902 by Herrick should be noted: "It is well to remember that, with serous and in a few cases even with purulent exudate, recovery has ensued either spontaneously or by the simpler measures of rest, compression, or aspiration".

The mortality rate is determined by the bacteraemia. In almost every joint infected by pneumococci, there will be some permanent damage. Evidence is lacking to establish a grave prognosis or high mortality for pneumococcic arthritis by itself.—*H. H. Beckering, M.D., Dallas, Texas.*

CAUSALGIA. A PRELIMINARY REPORT OF NINE CASES SUCCESSFULLY TREATED BY SURGICAL AND CHEMICAL INTERRUPTION OF THE SYMPATHETIC PATHWAYS. I. Joshua Speigel and Jack L. Milowsky. *The Journal of the American Medical Association,* CXXVII, 9, January 6, 1945.

The more important literature on the subject is reviewed, and the following etiological factors are mentioned: neuritis ascending from the point of injury; abnormal vasomotor reflexes; irritation of the peripheral sympathetic plexus; stimulation of a hitherto unrecognized set of "nocifensor nerves"; some anatomical or biological peculiarity of certain afferent neuronic systems; and "an expression of sensory hypertonicity". The authors agree with others that "all that emerges from these theories as reasonably certain is that abnormal vasomotor activity usually accompanies the pain". The therapy of causalgia is aimed at one of three expedients: removal of the cause of irritation to the nerve; interruption of the afferent pathway in the peripheral nerve; and interruption of the sympathetic supply of the extremity.

Removal of irritation to the nerve is accomplished by neurolysis, by removal of adjacent foreign bodies, or by the injection of "trigger points" with procaine hydrochloride. Interruption of the afferent pathway has been performed in several ways: by resection and resuture of the nerve; by section of the painful nerve, rhizotomy, or even chordotomy; and by injection of the nerve with 60 per cent. alcohol. Interruption of the sympathetic supply of the extremity has been done by periarterial sympathectomy, which is being supplanted in this country by direct surgical and chemical attack on the ganglionated sympathetic chain; and by preganglionic sympathectomy. A real disadvantage of postganglionic sympathectomy is the increased sensitization to circulating epinephrine and sympathin. A review of preganglionic sympathectomy is given, and the authors then present their nine successful cases.

On the basis of their experience, the following conclusions have been drawn: (1) the syndrome followed injury to all or any of the major nerves of the upper extremity; (2) injury to a blood vessel frequently accompanies nerve injuries in causalgia, but is not a necessary accompaniment; (3) the most constant symptom of causalgia is hot burning pain aggravated by movement and friction; (4) the most common findings are a shiny, cold, profusely perspiring and frequently cracked skin in the involved extremity, with hyperaesthesia occurring in most of the cases; (5) roentgenographic evidence of decalcification of the involved extremity is frequently seen; (6) the pain does not appear to be due to the constant irritation of a scar or of a foreign body; (7) the degree and quality of pain are in no way commensurate with the type and extent of the injury; (8) the sensory deficit does not delineate the area of pain, but the two frequently shade into each other; (9) personality disorders and hysteria are the result rather than the cause of causalgia.

Their conclusions as to therapy are: (1) neurolysis is not a useful procedure in the treatment of

causalgia *per se*, although it may be necessary in the treatment of the specific nerve deficit; (2) it is injudicious to subject the patient to a series of operations ranging through neurolysis, nerve section, and periarterial sympathectomy before attempting chemical and surgical interruption of the sympathetic pathways; (3) interruption of the sympathetic pathway, temporarily by sympathetic block, or permanently by surgical sympathectomy, is a highly dependable form of treatment for causalgia; (4) a series of diagnostic sympathetic blocks should be performed to prove the efficacy of interruption of the sympathetic pathway before performing sympathectomy; and (5) occasionally the pain of causalgia can be more or less permanently controlled by sympathetic block with local anaesthesia where sympathectomy is not feasible.—*Brandon Carrell, M.D., Dallas, Texas.*

PELLEGRINI-STIEDA DISEASE IN THE BANTU. P. Keen. *Clinical Proceedings. The Journal of the Cape Town Post-Graduate Medical Association*, III, 331, 1944.

In a group of 280 cases of injuries to the knee and chronic knee-joint conditions seen at the Non-European Hospital, Johannesburg, Pellegrini-Stieda disease was found seventeen times over a period of seventeen months.

The author states that, in the Bantu, the tibial collateral ligament is a larger structure (4.75 inches in average length, with extremes of 4.3 and 4.9 inches), whose insertion into the condyle of the femur is closely associated with that of the tendon of the adductor magnus. This anatomical difference is given as a reason for the spread of ossification beyond the ligament, and also for the conspicuous absence of lesions of the internal semilunar cartilage in the Bantu.

The average age in this group was 33.5 years. There were fifteen males, and two females. Definite trauma was noted in fourteen cases. In nine patients, the complaint was pain and stiffness; in seven, pain; and in one, pain and swelling. Ten of the seventeen cases gave roentgenographic evidence of osteo-arthritis, and two had clinical signs of it. The lesion of the tibial collateral ligament, however, overshadowed the evidences of osteo-arthritis where it was also present.

Excision of the ossified mass was indicated in some cases, but it could not be done because of the reluctance of the Bantu to undergo operative treatment. Immobilization with plaster-of-Paris was used, with absorption of the ossification in some. Massage, movements, and radiant heat helped to increase absorption.

Since closing the series, three other Bantu with Pellegrini-Stieda disease have been noted, making a total of twenty cases in about one and one-half years.

THE TREATMENT OF GUNSHOT INJURIES OF THE HIP JOINT IN FORWARD EVACUATION AREAS. M. A. Traitel. *Khirurgiya*, No. 4, 52, 1944.

The writer's experience covers a large number of hip-joint wounds and permits the following conclusions: (1) early radical surgical interference with excision of the joint is the operation of choice as a life-saving measure, and also as providing the most satisfactory functional result; (2) conservative treatment should be a rare exception and may only mean delay, which may prove to be fatal; (3) wounds involving contiguous areas, such as the pelvis, greater trochanter, intertrochanteric areas, and the surrounding soft tissues must also be subjected to early radical surgical interference.—*E. Kaplan, M.D., New York, N. Y.*

PAGET'S DISEASE: ITS PATHOLOGIC PHYSIOLOGY AND THE IMPORTANCE OF THIS IN THE COMPLICATIONS ARISING FROM FRACTURE AND IMMOBILIZATION. Edward C. Reifenstein, Jr., and Fuller Albright. *The New England Journal of Medicine*, CCXXXI, 343, 1944.

In the light of two carefully studied cases, this paper discusses the serious implications of acute atrophy of bone, as a complication of Paget's disease following fracture and immobilization. The paper should be read in full, since it also covers briefly normal bone metabolism, the metabolic abnormalities in osteoporosis, as opposed to those in osteomalacia and osteitis fibrosa generalisata, the morbid anatomy of Paget's disease, and, finally, a concept concerning the pathological physiology in Paget's disease.

The bone lesions found in Paget's disease are not generalized, but they are spotty, and this argues against an endocrinological or metabolic basis. The initial lesion is bone destruction, and its cause is entirely obscure. Destruction makes the involved bones less resistant to stress, and this leads to stimulation of the osteoblasts and overproduction of bone. However, the repair is not completed, because the localized initial disorder persists, and alternating destruction and repair produce the pathognomonic finding of the so-called "mosaic structure". This appearance is created by the irregular cement lines, each of which marks the point where destruction temporarily stopped and repair began. While the changes in Paget's disease are similar to those in osteitis fibrosa generalisata of hyperparathyroidism, there is one important difference. In the latter, bone is destroyed which can best be spared; while in Paget's disease destruction occurs without regard to structure.

A distinct train of events follows immobilization of a bone containing Paget's disease. The lack of stress, probably aided by the alarm reaction of Selye, reduces the activity of the osteoblasts, and the level of the serum phosphatase drops; but, because of the persistence of the initial bone-destroying

disturbance, there is an imbalance between bone destruction and bone formation. The increase of calcium and phosphorus coming from the bone leads to an increase in the urinary calcium and phosphorus. If the excretory capacity of the kidney is inadequate, hypercalcaemia results, and, unless this is overcome, "chemical death" may follow. Measures to overcome the hypercalcaemia are: an increase of fluid intake, a reduction in calcium intake, and as brief a period of immobilization as possible. Although the broken bone as a whole becomes decalcified, a calcifying callus promptly occurs at the fracture site. This supposedly is due to some local influence excited by the fracture, which stimulates the osteoblasts.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

Orthopedic Aspects of Brucellosis. E. G. Chuinard. *Northwest Medicine*, XLIII, 279, 1944.

There is not infrequently some confusion in the symptomatology and diagnosis of brucellosis and certain orthopaedic conditions. Aside from brucellosis spondylitis, this infection frequently localizes in tendinous insertions, especially in the supraspinatus, the glutei, the coccygeus, the levator ani, and the piriformis muscles. The main symptoms are weakness, fatigue, and soreness at the tendinous insertions, together with pains through the neck and head. The signs are tenderness at the tendinous insertions, and tenderness and weakness of the muscle. The fever signs are of less importance. The orthopaedic surgeon and the internist must work in close cooperation on these cases.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

Some Joint and Fracture Problems of the Accident Commission. Wilmer C. Smith. *Northwest Medicine*, XLIII, 360, 1944.

The author stresses the danger of permanent stiffness of the shoulder joint in injuries sustained after the fifth decade. It is imperative, therefore, that in immobilization of the shoulder joint, the humerus should be placed in a horizontal position, with the forearm fixed at right angles,—that is, pointing straight upward. This will permit maximum abduction as an end result. The author severely condemns unnecessary open reductions of fractures, and makes careful distinctions between delayed union and non-union. Prolonged and adequate immobilization in cases of delayed union will nearly always prevent non-union.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

Myelography with Pantopaque and a New Technic for Its Removal. Wendell G. Scott and Leonard T. Furlow. *Radiology*, XLIII, 241, 1944.

Neither air, lipiodol, nor thorotrast is an entirely satisfactory contrast medium for myelography. In search for a better one, Warren, Strain, Plati, and their associates developed ethyl iodophenylundecylate, a mixture of isomers obtained by the addition of iodobenzene to ethyl undecylate in the presence of aluminum chloride, and containing 30.5 per cent. of iodine in firm organic combination. It is called pantopaque, and is considered to be inert, there having been no reports, thus far, of meningeal irritation. Less viscid and lighter than lipiodol, but heavier than spinal fluid, it is more easily aspirated from the spinal canal. In the authors' experience, it is satisfactory for spinal myelography. The details of introduction and of examination are given. In the removal of pantopaque by the authors' method, no effort is made to aspirate by suction "since in so doing the nerve roots are frequently pulled against the needle and cause pain as well as block the exit of the oil". The needle, introduced squarely in the mid-line, is left in place during the examination and during the removal of the pantopaque.

For removal, the craniad portion of the column of oil is flowed beneath the tip of the needle, the stilette is removed, and spinal fluid bubbles out of the needle. The patient is then told to take a deep breath, and then bear down as though attempting to move his bowels. This is Valsalva's well-known experiment of forced expiration against a closed glottis, and has the effect of increasing intraspinal pressure. During this manoeuvre, the whole column of opaque oil moves craniad from 0.5 centimeter to as much as five to eight centimeters, and it becomes narrowed. These changes result from engorgement of the venous plexuses surrounding the dura. The thinner spinal fluid is displaced, leaving the oil in more intimate contact with the tip of the needle. The Valsalva manoeuvre is repeated until all the oil is removed,—usually within twenty minutes—the table being readjusted to keep the oil beneath the needle tip. All but a few drops of oil can be removed in this way.

The advantages of pantopaque over other contrast media are: increased fluidity, leading to more easy removal; lack of irritation; and absorbability, usually three cubic centimeters within a year.

Myelography is probably necessary only in those cases in which clinical signs of disc protrusion are not unequivocal, and in the identification of multiple protruded discs.—*Edward N. Reed, M.D., Santa Monica, California.*

Osteoporosis Circumscripta Cranii: Its Pathogenesis and Occurrence in Leontiasis Ossea and in Hyperparathyroidism. Frank Windholz. *Radiology*, XLIV, 14, January 1945.

Osteoporosis circumscripta cranii was first described by Schüller as large, irregular, circumscribed areas of osteoporosis in the cranium. Sosman demonstrated a histological relationship between osteoporosis circumscripta and Paget's disease. For a time this evidence seemed to be corroborated, and the lesions were thought to be an atypical form of Paget's disease, "probably the absorptive or destructive

phase with the productive phase held in abeyance". Schmorl first noted both gross and microscopic changes, which he considered to be a result of circulatory disturbances; they resembled hemorrhagic infarcts, rather than the anatomical changes found in Paget's disease. A third histological picture was noted by Schellenberg, one which resembled osteitis fibrosa.

Of the published cases of osteoporosis circumscripta, 60 per cent. have been associated with Paget's disease, and 20 per cent. with leontiasis ossea, or bony tumors of the maxilla. In a case in which osteoporosis was associated with a condition believed to be leontiasis ossea, the latter was variously interpreted as leontiasis ossea, Paget's disease, osteitis fibrosa, osteofibroma, and osteoma. Recently, the author observed a case of osteoporosis circumscripta with histologically verified leontiasis ossea (Virchow type).

Three cases are presented, two of leontiasis ossea, and one of hyperparathyroidism. One case was that of the Virchow type of leontiasis ossea. The histological picture was studied from a gum biopsy. This revealed: "Complete transformation of the bone tissue with hyperplasia due to osteoblast activity and simple metaplasia; fibrous bone marrow containing inflammatory cells and capillary blood vessels; bone resorption by osteoclasts with formation of small cavities." No hyperplasia or hyperostoses were seen in the vault. It was felt that the vault changes (osteoporosis) were secondary to the leontiasis ossea, but not intimately and topically connected with it.

Pathologically, two types of osteoporosis are known; one represents circulatory disturbances, with hemorrhagic changes and decalcification, and the other, Paget's disease. The hemorrhagic form may be considered a primitive non-specific reaction common to many diseases of the cranium, and one which may be followed by the characteristic mosaic structure and fibrous bone marrow of Paget's disease.

The second case described was one of fibrous osteodystrophy which clinically resembled leontiasis ossea. There were extensive hyperostoses of the cranium, surrounded by wide areas of osteoporosis, giving the impression that the osteoporosis was a change largely involving the vault.

The third case was one of hyperparathyroidism, proved by the removal of a parathyroid adenoma, which weighed seven grams. The localization and outline of the osteoporotic areas closely followed those of Paget's disease. They developed five years after the first cranial changes, thus suggesting a circulatory disturbance.

The pathogenesis of these lesions lies in circulatory disturbances caused by space-occupying lesions near the base of the skull or in the facial bones. Serial microscopy of biopsy specimens revealed obliterated blood vessels running into areas of quiescent bone tissue with no cellular reaction about the lamellae. Areas of primitive osteoporosis may undergo structural transformation corresponding to the demands of the statics of the vault.

Osteoporosis circumscripta cannot be regarded as a type or phase of Paget's disease or of any other disease entity. It occurs most often in Paget's disease, however, and frequently may be transformed into it. The "primitive" form of osteoporosis circumscripta is a characteristic reaction of the bones of the cranium, and is probably caused by circulatory disturbances in the presence of bony hyperplasias or of bony tumors near the base of the skull.—*William H. Wright, M.D., Santa Monica, California.*

La artritis deformante de las extremidades inferiores (Degenerative Arthritis in the Lower Extremities). R. Arguelles. *Revista Española de Cirugía, Traumatología y Ortopedia*, I, 97, 1944.

Arguelles reviews the progress which has been made in the study of degenerative arthritis in the lower extremity. Degenerative arthritis does not occur in articulations with normal form and function. It is also important to have the joint habitually used midway between the extremes of motion. In the hip, congenital abnormalities of the hip joint are among the chief causes of degenerative arthritis; congenital subluxation, as Calot has shown, leads to degenerative arthritis in later life. In the knee, genu varum or genu valgum, often insignificant in amount, leads to the formation of degenerative arthritis. The deformities mentioned by Jansen, "genu impressum" or "patella alta", may act as causative factors. The disease is often associated with flat feet; the bones of the foot under the weight-thrust go into internal rotation, then degenerative arthritis sets in in the mid-tarsal and astragaloscaphoid joints.

In treatment the author advises correction of static alterations. A brace can be used for genu varum or genu valgum. The hip can often be treated surgically. Osteotomy after the manner of McMurray is the usual procedure. If very severe pain is present, ankylosis is advised, but this can be used only in unilatera cases. Arthroplasty represents an ideal procedure in bilateral cases, but does not always relieve pain.—*John G. Kuhns, M.D., Boston, Massachusetts.*

Tumeurs malignes du squelette: histiocyto-sarcome et tumeur d'Ewing. (Malignant Tumors of the Skeleton. Histiocyto-Sarcoma and Ewing's Tumor). P. Lombard and J. Montpellier. *Revue d'Orthopédie et de Chirurgie de l'appareil Moteur*, XXVI, 717, 1939.

The authors report a case of bone tumor, which they believe had not been identified at the time of their description. They also report a case of Ewing's tumor by way of comparison.

The interpretation of this new type is somewhat difficult. It resembles the neoplasm recently described by Laffargue as "histiocyto-sarcoma" of the skin of the breast. The authors believe that the tumor

is a reticulosarcoma of the bone marrow with a simultaneous fibrocytic and histiocytic giant-cell evolution.

They give the following classification of reticulo-sarcomata:

1. Undifferentiated (Ewing's tumor);
2. Partly differentiated;
3. Differentiated: a. Reticulocytic; b. Reticulo-endothelial;
4. Progressing: a. Fibrocytic; b. Histiocytic; c. Lymphoblastic; d. Myeloblastic; e. Erythroblastic; f. Plasmocytic;
5. Metaplastic sarco-endothelial;
6. Complex (mixed) or intermediary.

The report is of unusual interest. — *E. Kaplan, M.D., New York, N. Y.*

THE DUAL PLATE, NO CAST, INTERNAL FIXATION OF SHAFT FRACTURES. Louis W. Breck and W. Compere Basom. *Southern Medical Journal*, XXXVII, 582, 1944.

In the dual-plate method, employed by the authors, one set of screws or bolts is used to fix two plates across the site of the fracture. No cast is necessary, as this method secures rigid fixation. It is especially useful in the lower third of the tibia, where non-union frequently occurs. A special jig is used to be sure the screws go in at right angles. One case of a simple, oblique fracture at the junction of the lower and middle thirds of the right tibia and fibula is reported and is illustrated. Six weeks after fixation, roentgenograms showed beginning union, and full weight-bearing was started. Three months later, good union was demonstrated. — *Fred G. Hodgson, M.D., Atlanta, Georgia.*

ISTHMUS DEFECTS OF THE FIFTH LUMBAR VERTEBRA. R. Beverly Raney. *Southern Medical Journal*, XXXVIII, 166, March 1945.

An isthmus defect of the fifth lumbar vertebra may be unilateral or bilateral. This defect is a significant factor in the cause of backache. It is not uncommon, as shown by roentgenograms and examination of skeletons. It is found in about 5 per cent. of skeletons examined, from different countries and in various races. In a series of 300 patients complaining of low-back pain, with or without sciatica, it was discovered in ninety-four, or 31 per cent.; in sixty-three the defect was bilateral.

The gross appearance of the tissue within the defect is that of fibrous tissue. Microscopic examination shows fibrous tissue and a gradual transition between it and the bone on either side of the defect. The spinous process is hypermobile, especially in bilateral cases. The cause is supposed to be congenital, or possibly a fracture sustained at birth. The chief complaints are low-back pain, weakness, and stiffness. Pain is increased by mechanical stress. Involvement of nerves of the lower extremities may be evidenced by radiating pains, usually sciatic in distribution, accompanied at times by areas of numbness and tingling. Muscle spasm and tenderness of the low back may be present. If the nerves to the lower extremities are affected, physical signs may include decreased reflex responses, and even muscle weakness. Roentgenographic examination is most important, especially oblique projections.

Treatment in most cases should be conservative, with a firm mattress and a fracture board at night. A plaster body jacket or a strong, well-fitted corset is advised for ambulatory use; heat and massage for relief of pain, together with graded exercises to improve posture and muscle strength. Removal of foci of infection, and administration of large doses of vitamins help in some cases. Spine fusion is recommended for patients not relieved by conservative measures. — *Fred G. Hodgson, M.D., Atlanta, Georgia.*

TRAUMATIC OSTEOCHONDRITIS OF THE PATELLA. Francis J. Cox. *Surgery*, XVII, 93, January 1945.

The author states that diffuse osteochondritis of the patella can result from trauma, and he reports six such cases. Following trauma, the acute symptoms subside, and for weeks or months the knee is apparently normal; then appears a low-grade chronic effusion with pain and discomfort, and locking or snapping. The average duration of symptoms in these cases was 13.2 months. The author performed a patellectomy, and found softening and fissures of the patella with a yellowish articular cartilage. There were thickening, hyperaemia, and villous degeneration of the synovial membrane, usually confined to the suprapatellar pouch. Increased fluid was found, as well as pannus formation at the edges of the articular cartilage of the patella and the femoral condyles.

The patellectomy performed on these six patients entirely relieved and alleviated the symptoms, and resulted in the disappearance of the inflammatory changes of the synovial membrane. — *Lee M. Cattell, M.D., Chicago, Illinois.*

TREATMENT OF TENDONS IN FINGER AMPUTATIONS AND DESCRIPTION OF A NEW INSTRUMENT. George V. Webster. *Surgery*, XVII, 102, January 1945.

Commander Webster discusses the attachment of the tendons of the finger and the treatment of tendons in amputations. He states: "Flexor tendons need not be sutured to bone or tendon sheath in clean cases, and must not be overlapped and sutured over the end of the bone to the extensor ten-

dons". It is better to allow the tendons to retract within the sheath. The author recommends that, if the wound is contaminated, the tendons be anchored at the point of amputation, and the tendon sheath be left open to avoid spread of the infection. Such tendons often become adherent and cause loss of function. In such cases, they should be excised. A tendon stripper, suitable for freeing such tendons, is described.—*Lee M. Cattell, M.D., Chicago, Illinois.*

THE CONSERVATIVE AND OPERATIVE TREATMENT OF LESIONS OF THE INTERVERTEBRAL DISCS IN THE LOW BACK. J. Albert Key. *Surgery*, XVII, 291, February 1945.

Dr. Key believes that more and more of the symptoms, previously attributed to sacro-iliac or lumbosacral strains, arthritis, subluxation, the lumbosacral facet syndrome, or postural strains of the low back, are really due to lesions of the intervertebral discs in this area. The author divides patients with low-back pain into three groups:

1. *Ambulatory patients* are treated by support to the low back, manipulation, stretching, and correction of the body mechanics by exercise, a hard bed, vitamin B, weight correction, salicylates, and a change of occupation if necessary.

2. *Bed patients* are those whose symptoms are so severe that they are not able to carry on their daily routine. Many of these people must now be treated at home, rather than in a hospital. The author recommends bed rest on a rigid bed with flexion of the lumbar spine, local heat, hot tubs, and exercises, with medication for pain as necessary. Occasionally manipulation under anaesthesia may be used.

3. *Surgical patients* are those patients for whom an adequate program of conservative treatment has been tried and proved unsuccessful. For such patients surgical removal of the herniated nucleus, with or without spine fusion, is recommended. The author describes the operative technique in detail. In 120 consecutive operations for ruptured intervertebral discs, the author reports only one fatal case.—*Lee M. Cattell, M.D., Chicago, Illinois.*

VASCULAR INSUFFICIENCY OF THE LOWER EXTREMITY DUE TO OSTEOMA OF THE FEMUR. Robert M. Rankin. *Surgery*, XVII, 419, March 1945.

The author reports a case of a white male, forty-eight years of age, who complained of progressively severe intermittent claudication. This was relieved by the removal of an osteoma of the femur, which had been compressing the femoral artery and vein for at least four years. There was secondary arteriosclerosis present at the site of the compression. Symptomatic relief following surgery was dramatic, despite the failure of the arterial pulsations in the foot to return to normal.—*Lee M. Cattell, M.D., Chicago, Illinois.*

BONE REGENERATION FOLLOWING OSTEOMYELITIS. Laurence H. Mayers. *Surgery*, XVII, 463, March 1945.

The author reports a human bite of the left middle finger in a male, forty years of age, which caused osteomyelitis. Pyogenic organisms, spirilla, and anaerobes were all cultured from the wound as the case progressed. By frequent roentgenograms the progress of the destruction and the regeneration of bone was carefully followed. Treatment covered the conventional range and was all directed toward giving the phagocytic type of cell a chance to work to the maximum advantage. The finger was reopened five weeks after the initial wound, and a small amount of necrotic tissue was found. It was five and a quarter months before there was roentgenographic evidence that the bone atrophy had disappeared, and the cortex was commencing to reappear. This patient has a usable finger, although the terminal joint is partially ankylosed.—*Lee M. Cattell, M.D., Chicago, Illinois.*

A NEWER METHOD IN THE TREATMENT OF FRACTURES OF THE OS CALCIS. Ben L. Schoolfield. *Texas State Journal of Medicine*, XL, 294, 1944.

A method for internal fixation of fragments and for reduction of lateral displacement in fractures of the body of the calcaneus is described.

A vise, adequately padded, is applied and screwed up firmly over the sides of the displaced fragments just below the tips of the malleoli. The lateral displacement is reduced and checked roentgenographically. A Steinmann pin is then introduced through the middle of the posterior surface of the heel. It is directed obliquely forward and upward. Any upward tilting of the posterior fragment is corrected by depressing the drill and pin, after which the pin is driven into the anterior fragment for fixation. The vise is then removed, and a padded plaster-of-Paris dressing is applied to the limb, from the toes to just below the knee. During application of the plaster, the posterior part of the heel is depressed to maintain alignment, the forefoot is depressed in countertraction, while the foot is fixed at a right angle to the leg with a mild varus tilt.

After six weeks the cast is removed. If union of the fragments appears to be progressing, the Steinmann pin is taken out; otherwise it is left in and the plaster is re-applied. Union is determined by roentgenogram.

Some swelling of the foot and ankle, with localized tenderness, may be expected. Weight-bearing is allowed when solid union has taken place.

The author has treated several cases of fracture of the body of the calcaneus in the past two years, with satisfactory results in all.

In some cases where the fracture line has penetrated the subtalar joint, traumatic arthritis has been observed, the result of improper reduction and fixation. Such an end result is unlikely, if restoration of the joint surfaces has been carried out along anatomical lines

FRACTURES OF TRANSVERSE PROCESSES OF LUMBAR VERTEBRAE. Jesse T. Nicholson and John H. Allan. *United States Naval Medical Bulletin*, XLII, 780, 1944.

The authors cite nineteen cases of fractures of the transverse processes of the lumbar vertebrae treated aboard a hospital ship by local injections of procaine, and early mobilizing exercises. They consider the local contusion and tearing of muscle structure the important pathology. The quadratus lumborum originates from the crest of the ilium, and is inserted into all five lumbar transverse processes and into the twelfth rib. The iliopsoas also arises from all five vertebrae, and is inserted into the lesser trochanter of the femur. All previous treatment has included prolonged rest in bed, plaster jackets, braces, and inactivity, work being out of the question for three to six months. The authors stress the importance of getting men back to active duty on board ship.

In the authors' cases, the transverse processes most frequently injured were those of the second, third, and fourth lumbar vertebrae. Treatment consisted of thorough infiltration of the soft tissues around the affected area with ten cubic centimeters of a 1 per cent. solution of procaine. This was done every three days for four doses. Immediately following these injections, the patient performed exercises, such as (1) raising his back and shoulders up from the prone position, (2) rotating his shoulders first to the right and then to the left, while in a sitting position, (3) lateral bending, (4) touching the deck with his fingers from a standing position. Each of the exercises was done fifteen times, and was repeated twice daily.

The authors base their good results on Leriche's theory that procaine (1) eliminates the reflex arc of pain, (2) activates early mobilization, and (3) interrupts vasomotor phenomena. They claim that active motion eliminates the scar which is brought about by exudate around the nerves and muscles.—*A. J. Langan, M.D., Iowa City, Iowa.*

GRAMICIDIN S AND ITS USE IN THE TREATMENT OF INFECTED WOUNDS. G. F. Gause and M. G. Brazhnikova. *War Medicine*, VI, 180, 1944.

Gramicidin is one of the newer and as yet little used agents in the treatment of infections. The technical name for this substance, tyrothricin, is gradually becoming more widely accepted. The substance is extracted from the bacteria of certain soils. Apparently there are several different variations including gramicidin prepared by Gause and Brazhnikova, tyrothricin, gramicidin of Dubos, and tirocidine hydrochloride. Gramacidin S, described in this article, was found to be highly bactericidal for staphylococci, streptococci, pneumococci, and the more common gas-producing bacilli.

The substance is as toxic as tyrothricin. It is used in the same way for local application to infected wounds.—*Edward L. Compere, M.D., Chicago, Illinois.*

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